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Libertyville, IL

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This report presents state-of-the-art information for implementing cost effective and environmentally sound solutions to the nationwide problem of septic tank sludge (septage) treatment and disposal.

Current hauler practices, septage characterization, and regulatory control are presented. Design concepts of full scale and pilot installations are presented for land disposal schemes, for separate septage treatment processes in areas with sufficient septage volumes to support such a facility, and for septage disposal at sewage treatment plants (STP). Actual system costs and environmental and socio-economic acceptability for many actual and proposed treatment schemes are detailed to assist in the selection of the best treatment scheme for a particular locale at the least possible cost.

A significant bibliography is presented which embodies most of the pertinent U.S. references on the subject.

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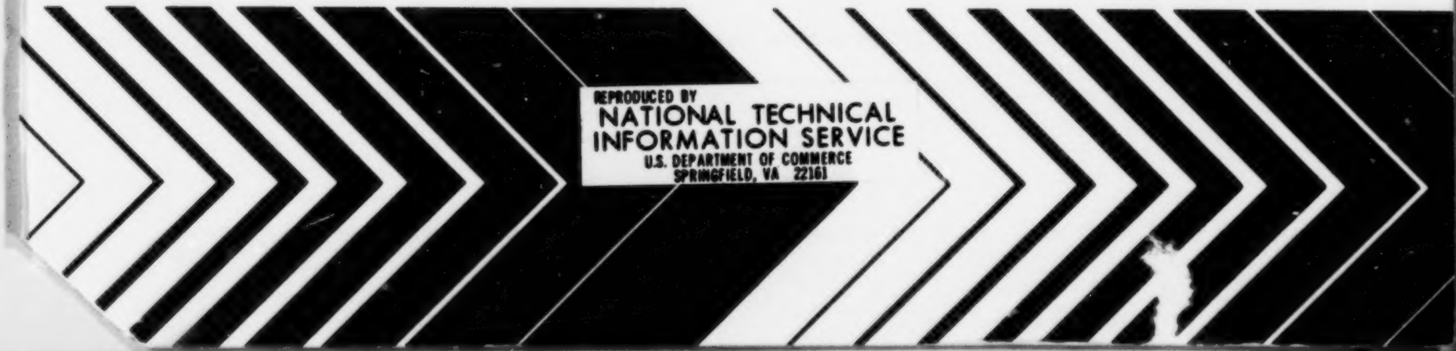

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SEPTAGE MANAGEMENT

by

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Contract Number 68-03-2231

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

This study represents a significant effort to document the state of the art of the treatment, disposal and management of septic tank pumpings in the United States. This source of treatment residuals, often referred to as "septage", represents a major public health and environmental hazard which is particularly vexing due to its overall volume and its diffuse nature of generation. By documenting some of the more enlightened techniques of septage management employed at certain locations, this report represents a major contribution to those charged with these responsibilities throughout the country.

Francis T. Mayo
Director
Municipal Environmental
Research Laboratory
Office of Research and Development

ABSTRACT

This report presents state-of-the-art information for implementing cost effective and environmentally sound solutions to the nationwide problem of septic tank sludge (septage) treatment and disposal.

Current hauler practices, septage characterization, and regulatory control are presented. Design concepts of full scale and pilot installations are presented for land disposal schemes, for separate septage treatment processes in areas with sufficient septage volumes to support such a facility, and for septage disposal at sewage treatment plants (STP). Actual system costs and environmental and socio-economic acceptability for many actual and proposed treatment schemes are detailed to assist in the selection of the best treatment scheme for a particular locale at the least possible cost.

This report was submitted in fulfillment of Contract number 68-03-2231 by Rezek, Henry, Meisenheimer, and Gende, Inc., under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period from July 1975 to April 1977, and work was completed as of April 1977.

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SECTION 1

INTRODUCTION

The use of a septic system requires periodic maintenance which includes pumping out the accumulated scum and sludge, called septage. Kolega (1) has reported septage volumes pumped between 190 to 265 l (50 to 70 gal) per capita per year in properly functioning septic systems. Some states suggest septage accumulations ranging from 190 to 265 l (50 to 70 gal) per capita per year in Connecticut to 3.8 l (1 gal) per capita per day in Massachusetts.

Various recommendations exist for time periods for septic tank pumping, with most recommendations between 2 and 5 years. After a hauler pumps out the homeowner's septage, this highly offensive sludge must be disposed of in a safe, cost-effective, and convenient manner.

An extrapolation of Vesilind's estimate for the annual volume of domestic STP sludge slated for disposal yields approximately 92 million m^3 (24,300 million gal) per year of an assumed 4% digested sludge in the United States. (2) Thus, the estimate of 15.67 million m^3 (4,100 million gal) per year of septage to be disposed of annually indicates that a volume equal to an additional 20% of the domestic treatment plant digested sludge problem has been essentially overlooked.

Septage is generally placed on the land, in lagoons, in sanitary landfills, or in wastewater treatment facilities. With increasing public awareness of environmental pollution and stricter regulatory enforcement of groundwater quality, leachate control, surface water quality, and odor control, numerous disposal facilities have refused acceptance of the material, focusing attention on septage treatment and disposal as a legitimate problem. In many cases, waste treatment operators have justifiable concerns in treating septage, since the material may have previously created an organic overload in a treatment plant, causing a violation of water quality standards, or added too much liquid in a sanitary landfill creating a leachate hazard.

The major objective of this study is to bring together material from highly specialized technical works and the more general, overview type management reports to form a broad background and evaluative decision factors which provides a rational format for design and operation of treatment facilities. This basis should pre-empt previous practices which led to operational problems.

The initial work to achieve the objective centered on review of the information and laboratory research of septage treatment and disposal. Additional information was obtained from various levels of government including municipalities and sanitary districts. Hauler practices complimented this area. The majority of the work was conducted in gathering and evaluating data from successful installations treating septage to obtain secure design criteria and cost data. This latter information provides the foundation for the systematic selection method for choosing the best suited treatment or disposal option for any given situation, and is presented in Section 7. Literature search and data collection was performed during the period of 1975 - 1977.

SECTION 2

SUMMARY AND CONCLUSIONS

This report investigated several areas in present day septage treatment and disposal practice. The usage of septic tank systems and generation of septage was detailed on a state by state basis, with the majority of the 16.6 million housing units with septic tanks located in the Northeast, the Southeast, and the Pacific Northwest regions of the United States. The total annual septage generation in the U. S. was estimated to be over 15.7 million m^3 (4.1 billion gal).

Septage is a highly variable waste, with BOD_5 and suspended solids (SS) concentrations similar to wastewater. Heavy metal content of septage is 1/2 to 2 orders of magnitude less than STP sludge.

Septage may exhibit various offensive characteristics, such as the ability to create vast quantities of foam when aerated, a highly pervasive and obnoxious odor, poor settleability, and poor dewaterability. These qualities make septage a less than desirable material to treat properly.

The problems associated with septage treatment and disposal have been addressed in detail only in the last few years. The body of information is beginning to accumulate as political and environmental pressure force attention on this issue.

Statewide septage disposal regulations are often missing or are enacted on a case by case basis to meet immediate needs. Often, state officials comment that septage problems are on "the back burner". Some states are beginning to address the issue with effective and comprehensive areawide programs. One excellent example of a comprehensive statewide program is found in Maine, where Title 30, Sections 4104 and 4105 require each municipality to provide an acceptable disposal site. This program is backed with effective licensing, monitoring, research, and enforcement efforts.

Frequently 208 programs failed to identify septage disposal problems. If these programs did address this topic, their importance has usually been minimized.

Existing and proposed septage treatment and disposal options have been identified and evaluated, including:

- Land Based Disposal
    - Spray Irrigation
    - Ridge and Furrow
    - Land Spreading
    - Subsurface Injection
    - Burial
    - Trenching
    - Disposal Lagoons
    - Sanitary Landfills
    - Leaching Lagoons
    - Marsh/Pond
    - Meadow/Marsh/Pond

- Separate Septage Treatment Systems
    - Aerated Lagoons
    - Anaerobic/Aerobic Process
    - Composting
    - Pressure Chlorination
    - Rotating Biological Contactors
    - Wet Air Oxidation
    - Autothermal Aerobic Digestion
    - Chemical Precipitation/Stabilization

- Septage Treatment at Sewage Treatment Plant
    - Receiving Stations
    - Primary Treatment
    - Activated Sludge by Slug Addition
    - Activated Sludge by Controlled Addition
    - Attached Growth Systems
    - Aerobic Digestion
    - Anaerobic Digestion
    - Mechanical Dewatering
    - Sand Bed Drying

Under the proper conditions, direct land disposal of septage may prove most economical.

The placement of septage into lagoon systems with filtrate applied to infiltration beds has been shown to be a cost-effective solution, but should be applied in low density areas if groundwater levels are known to maintain a substantial distance below the surface. Management problems with lagoons consist of bucketing out very wet solids periodically for final disposal elsewhere. Often additional dry soil is added to the lagoon solids to obtain a truckable mixture.

In more densely populated areas, the addition of degritted and equalized septage into a STP solids stream works well if excess digestion or solids handling capacity exists. Separate solids treatment of septage at an STP could include liming and sand bed drying in an STP at or near design loading. This method, however, is more costly than utilizing existing solids handling facilities.

Septage disposal into the liquid stream of STP can be practiced if a facility has the capacity to handle additional organic loadings fed continuously. Also, liquid stream disposal will contribute to a larger volume of sludge for treatment than if septage were placed in the solids stream directly, because excess waste activated sludge is typically at 0.5 to 1.0% solids concentration, whereas septage may range from this level up to 5 to 8% solids. Foaming problems do not seem to be a drawback to placement in an activated sludge flow; however, this precaution would apply to aerobic digestion unless design considerations include effective foam control.

In areas where it is not feasible to place septage in a land based system or in a sewage treatment facility, independent septage treatment plants should be considered. Composting is one of the most practical of these alternates when evaluated in terms of both cost effectiveness and environmental acceptance. Greater acceptance of this method will require additional work in the final product marketing area.

Other separate treatment schemes include chemical coagulation, lime stabilization, wet air oxidation, and chlorine (Cl) oxidation. These methods suffer from economic drawbacks, but all have been shown to treat septage effectively. The fate of chemically stabilized septage is unknown. The significance and fate of Cl compounds formed during pressure chlorination of septage needs further research.

Of all the alternatives investigated, land disposal had the lowest associated operation and maintenance cost reported, from less than \$1.00 to \$5.00 per 3.8 m^3 (1000 gal), exclusive of the cost of the land. Various lagoon systems report the cost of treatment between \$5.00 and \$10.00 per 3.8 m^3 (1,000 gal). The cost of septage treatment in STPs varies widely, but typically average \$15.00 per 3.8 m^3 (1000 gal) with solids stream processing showing slightly lower costs. Composting by the Lebo process is reported to cost approximately the same as disposal in wastewater treatment plants. Cost for physical-chemical treatment, such as the Purifax process or chemical stabilization, range from those found for disposal at treatment plants to triple that figure.

SECTION 3

RECOMMENDATIONS

Further research or study is needed to remedy the following problem areas in present practice or to obtain needed information for more efficient management and design of septage treatment facilities.

MANAGEMENT

* Improved design of septic tanks to facilitate pumpout.
* Contingency plans for septage disposal when small STP's normally receiving septage are closed.
* Nationwide licensing and registering of haulers after meeting certain professional and job related educational requirements.
* Legislative guidelines requiring septic systems to be inspected and pumped, if necessary, on a predetermined schedule.
* Inspection and pumping, if necessary, before a home can be sold.
* Periodic state review of existing regulations in light of current needs.
* Minimum standards for hauler equipment and annual inspection of equipment.
* Requiring haulers maintain accurate files of date septic tank system serviced, volume transported, and disposal site utilized. Haulers could report results annually.
* User fees for septage treatment based on capital recovery and operation and maintenance costs.

DESIGN

Further research needs are listed below to determine costs and applicability for septage treatment in the following areas:

- Innovative designs such as Marsh/Pond systems and Autothermal Thermophilic Aerobic Digestion (ATAD) technique.
- The fate of chemically stabilized sludge applied to the land or to a landfill.
- Clarifier sizing on physical chemical stabilization processes.
- Survival of viruses, ova, and cysts in limed septage.
- Market development for composted septage products.
- Treatability of dewatering filtrates and fate of sludge cakes from different disposal schemes.
- Quality and volumes of excess sludge produced from septage addition to both liquid and solids flow streams in STP's.

SECTION 4

PROBLEM DEFINITION

GENERAL

Major source categories of septage producers include domestic, commercial, institutional, and industrial. Septage volumes and characterizations are available for domestic septage, but are lacking for other categories. Results of the 1970 census informs us that 16.6 million housing units, or over 24.5% of the total housing units in the United States, relied on septic systems for wastewater disposal. (3)

The individual septic tank system is shown in Figure 1. Wastewater enters the septic tank where heavy material settles, while grease and scum float. The clarified liquid, or septic tank effluent, then flows to the disposal area. The liquid is distributed into the soil mantle by drain tile or seepage pits for further purification, eventually entering the local groundwater regime. In poor soil areas, other disposal options are available following the septic tank, such as evapotranspiration and mound systems.

GEOGRAPHICAL DISTRIBUTION

The geographical distribution of domestic septic systems, Figure 2, shows states with over 35% usage located in New England, the Southeast, and the Pacific Northwest. The Southwestern states' usage of septic tanks is between 10% and 20%. On a local level, Table 1 shows many counties in New Jersey, New York, and California and other states have over 50,000 housing units which use on-site waste disposal systems, while their statewide usage appears less significant. Areas with over 100,000 housing units using on-site waste disposal systems include suburban New York, Los Angeles, and Miami. (4)

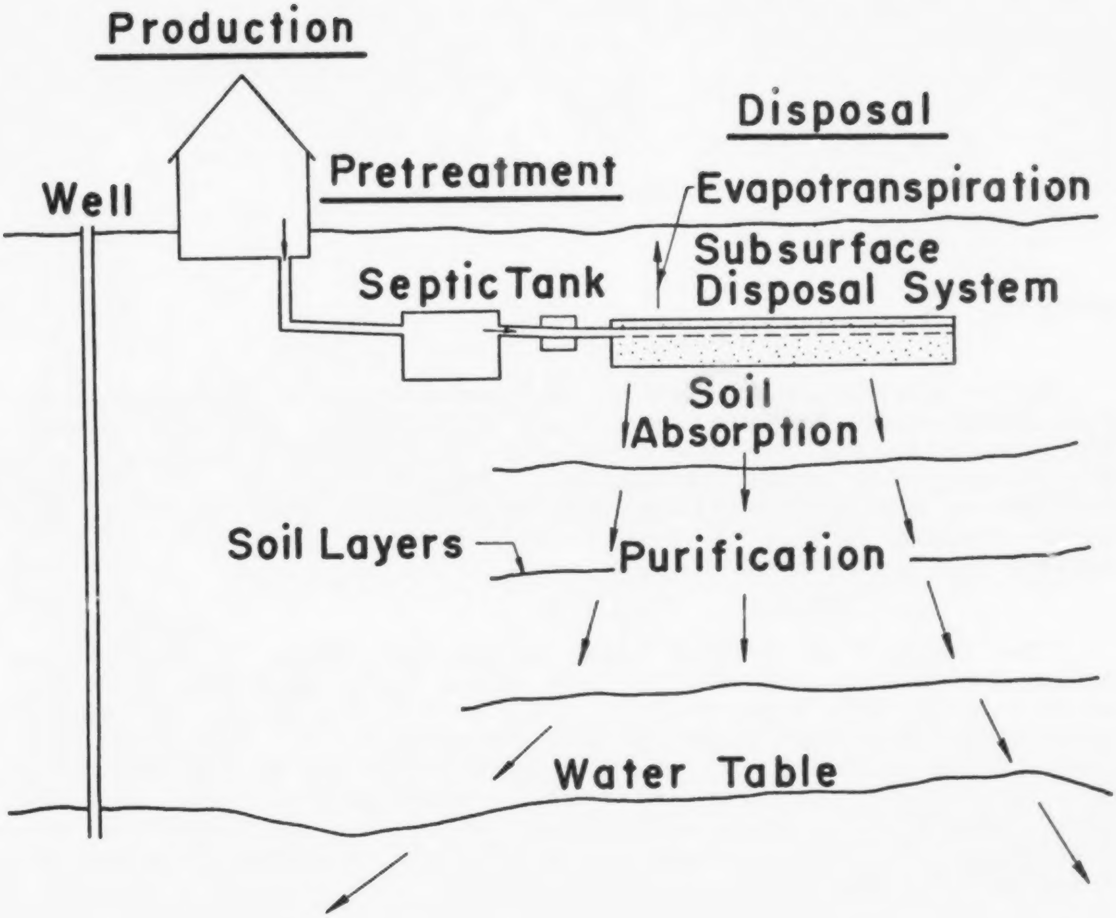
Production
Disposal
Pretreatment
Evapotranspiration
Well
Subsurface
Disposal System
Septic Tank
Soil
Absorption
Soil Layers
Purification
Water Table

Figure 1. Diagram of a typical domestic septic tank system.

Table 2 presents the actual data from which Figure 2 was created. Factors considered by the census bureau were the number of housing units and the percent of total housing units in each state served by either sewers, septic tank - cesspool systems, or housing units lacking either of the above disposal methods.

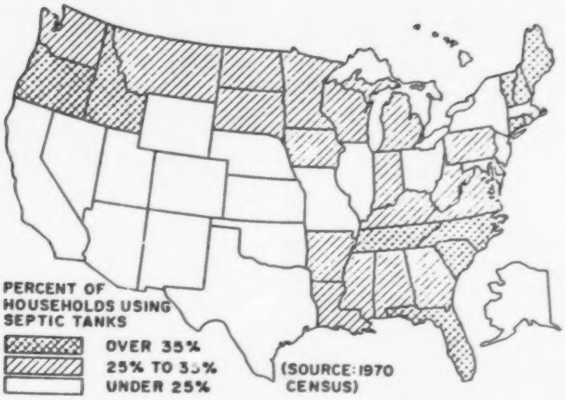
PERCENT OF HOUSEHOLDS USING SEPTIC TANKS
OVER 35%
25% TO 35%
UNDER 25%
(SOURCE: 1970 CENSUS)

Figure 2. Distribution of on-site domestic septic systems, by state, in the United States.

TABLE 1. COUNTIES WITH MORE THAN 50,000 AND COUNTIES WITH MORE THAN 100,000 HOUSING UNITS USING ON-SITE DOMESTIC WASTE DISPOSAL SYSTEMS

More than 50,000

Jefferson, AL
Riverside, CA
San Bernardino, CA
Fairfield, CT
Hartford, CT
New Haven, CT
Broward, FL
Duval, FL
Hillsborough, FL
Jefferson, KY
Bristol, MA
Middlesex, MA
Norfolk, MA
Plymouth, MA
Worcester, MA
Genessee, MI
Oakland, MI
Monmouth, NJ
Multanannah, OR
Westmoreland, PA
Davidson, TN
King, WA
Pierce, WA

More than 100,000

Los Angeles, CA
Dade, FL
Nassau, NY
Suffolk, NY

TABLE 2. SEWAGE DISPOSAL CHARACTERISTICS FOR THE UNITED STATES FROM 1970 CENSUS (3)

State	Housing Units on Public Sewers Number	Housing Units on Public Sewers % of Total	Housing Units with Septic Tanks Number	Housing Units with Septic Tanks % of Total	Housing Units with Other Number	Housing Units with Other % of Total
AL	566,307	50.80	385,345	34.56	163,139	14.63
AK	55,511	62.69	18,629	21.03	14,423	16.29
AZ	446,304	77.11	114,433	19.77	18,013	3.11
AR	355,684	52.85	220,287	32.73	96,999	14.41
CA	6,084,632	87.22	853,013	12.23	38,324	0.55
CO	612,659	82.47	113,290	15.25	16,689	2.25
CT	608,603	62.82	354,585	36.60	5,633	0.58
DE	130,259	74.44	39,860	22.78	4,870	2.78
DC	277,068	99.52	454	0.16	871	0.31
FL	1,509,682	60.61	938,352	37.67	42,743	1.72
GA	848,516	57.85	474,455	32.35	143,654	9.79
HI	161,438	74.78	50,558	23.42	3,844	1.78
ID	137,891	57.87	93,146	39.09	7,266	3.05
IL	3,072,266	83.20	554,603	15.02	65,080	1.76
IN	1,060,942	61.97	589,794	34.45	61,061	3.57
IA	662,320	69.35	257,889	27.00	34,829	3.65
KS	594,758	75.52	163,918	20.82	28,808	3.66
KY	536,388	50.57	312,856	29.50	211,328	19.93
LA	778,247	67.90	287,481	25.08	80,245	7.01
ME	169,975	50.11	140,409	41.39	28,817	8.50
MD	953,470	77.23	243,728	19.74	37,271	3.02
MA	1,339,304	72.83	490,365	26.67	9,120	0.50
MI	1,947,137	68.43	847,433	29.78	50,509	1.78
MN	864,984	70.92	307,441	25.21	47,070	3.86
MS	338,581	48.56	209,115	30.00	149,514	21.44
MO	1,173,688	70.47	359,278	21.57	132,617	7.96
MT	154,581	64.21	74,198	30.82	11,974	4.97
NE	385,860	75.44	105,320	20.59	20,266	3.96
NV	147,743	86.07	21,988	12.81	1,951	1.13
NH	132,475	53.26	109,015	43.83	7,231	2.91
NJ	1,890,977	82.03	404,241	17.53	10,123	0.44
NM	230,737	71.60	65,781	20.42	25,722	7.98
NY	4,824,525	98.34	1,289,253	20.93	44,883	0.73
NC	733,848	45.32	687,572	42.46	197,859	12.22
ND	128,967	64.32	53,074	26.47	18,457	9.21
OH	2,565,317	74.41	779,510	22.61	102,566	2.98
OK	686,240	73.17	203,174	21.66	48,413	5.16
OR	448,967	61.04	275,944	37.52	10,559	1.44
PA	2,798,522	72.13	985,014	25.39	96,502	2.48
RI	197,947	64.41	107,544	34.99	1,843	0.60
SC	363,611	45.18	334,210	41.53	106,996	13.29
SD	140,258	63.30	62,366	28.14	18,970	8.56
TN	671,248	51.76	457,008	35.24	168,672	13.00
TX	2,989,684	78.49	654,283	17.18	164,950	4.33
UT	258,649	82.93	49,249	15.79	3,976	1.28
VT	72,264	48.23	68,265	45.56	9,315	6.21
VA	906,030	71.02	408,213	27.49	170,580	11.49
WA	786,551	65.28	403,909	33.52	14,464	1.20
WV	304,151	51.31	187,028	31.55	101,600	17.14
WI	994,926	70.26	371,567	26.24	49,549	3.50
WY	86,983	75.94	23,349	20.38	4,217	3.68
U.S.	48,187,675	71.18	16,601,792	24.52	2,904,375	4.30
Ter.						
PR	346,830	48.87	112,595	15.86	250,308	35.27
VI	IU*					
GU	IU					
AS	IU					
CZ	IU					
Trust Ter. of the Pacific Islands	IU					
Total U.S. and Ter.	48,534,505	70.95	16,714,387	24.43	3,154,683	4.61
Total Housing Units U. S. and Ter.	68,403,575					

*Information Unavailable.

Normal maintenance of a septic tank system requires the user to inspect periodically the buildup of sludge and scum in the septic tank. Pumping is required when the bottom of the scum mat is within 7.6 cm (3 in) of the bottom of the outlet tee, or the level of sludge comes close to the bottom of the outlet device (example: 10.2 cm (4 in) in a 3.8 m^3 (1000 gal) septic tank with 91 cm (3 ft) liquid depth). (5) Such a condition is present in Figure 3. The hauler has uncovered the access manhole to the septic tank, lowered the flexible suction pipe into the liquid, and is ready to pump out the septic tank's contents. If the septic tank is not pumped when the above limits are reached, it will be unable to perform its settling and flotation functions, allowing most of the influent SS and hexane solubles (grease) to be carried out to the distribution field. Plugging of the soil structure is greatly accelerated, resulting in a premature system failure.

SEPTAGE GENERATION

Several methods are available for obtaining the volumes and frequency of septage to be disposed of in an area. Septage haulers have been surveyed in the states of Massachusetts and Oregon. Unfortunately, fewer than 50% of those contacted responded. Records of the responding pumpers have been examined for volume and frequency of pumpings.

In Massachusetts, volumes of septage generated range from 0.190 to 0.265 m^3 per capita per day (0.72 to 1 gal per capita per day). (6) Homes with few elderly residents in a warm climate in Orange County, FL have been known to not require pumping for up to 25 years. (7) In a study in Wayland, MA, 1705 residents responded that their system was last pumped out an average of 3.24 years ago. (8) The same residents reported they regularly have their tanks pumped at 3.21 year intervals. Haulers report most commercial/institutional/industrial systems receiving domestic wastes are pumped annually.

A reliable estimate of the annual septage generation by state is shown in Table 3. It was estimated that each housing unit has a 3.8 m^3 (1,000 gal) septic tank pumped at an average interval of 4 years. This estimate assumes 4.0 persons per housing unit served by a septic tank, generating 237 l (62.5 gal) septage per capita per year. These computations result in an annual septage generation estimate of 15.67 million m^3 (4,100 million gal) of septage.

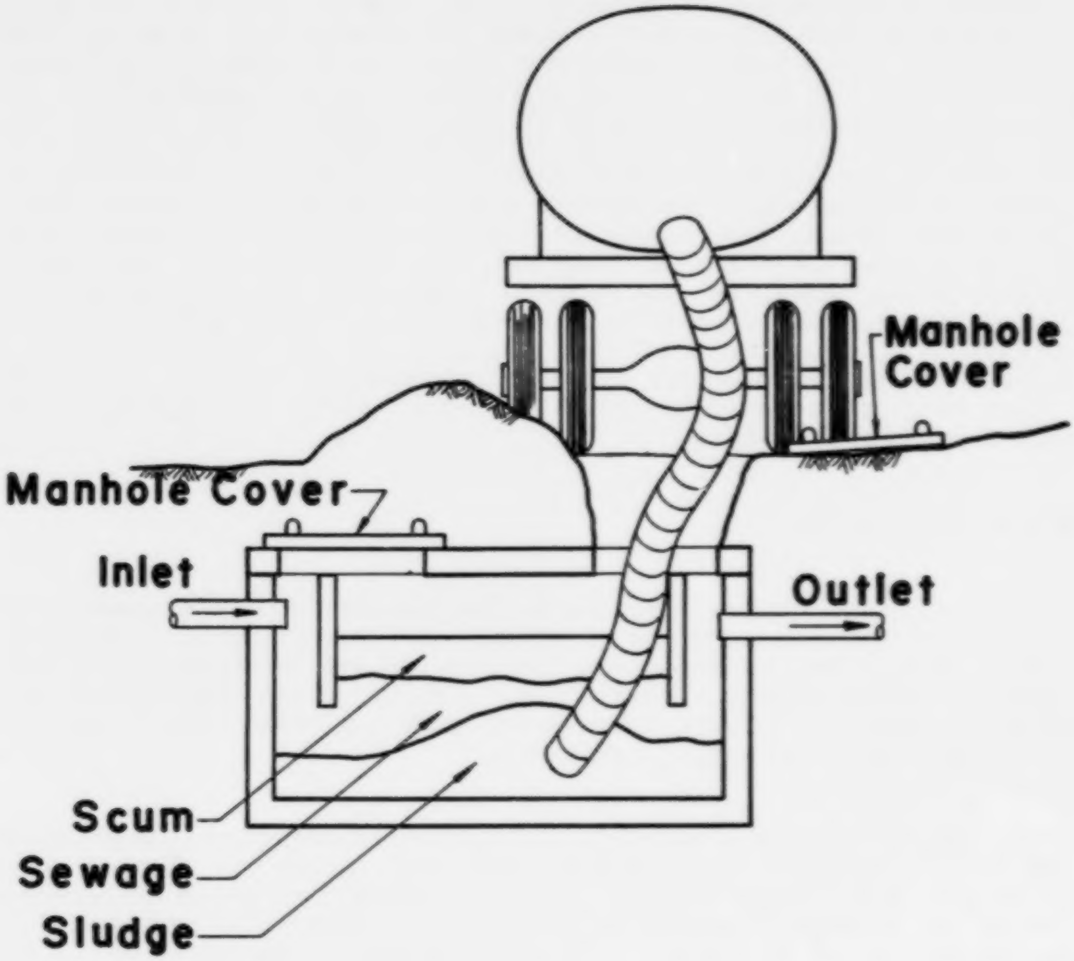

Figure 3. Hauler pumping out septic tank contents (septage) from access manhole.

This estimate of U.S. septage generation lacks consideration in terms of geographical distribution by locality, as well as daily, weekly, monthly, or seasonal variations. Patterns on Long Island exhibit a daily variation of septage deliveries to treatment works on Mondays and days following holidays that are 20 to 40% heavier than the average for the week, with peak days sometimes running as high as 5 times the daily load. (9) The New England Interstate Water Pollution Control Commission (NEIWPCC) indicates that climate (especially precipitation),

TABLE 3. ESTIMATED HOUSEHOLD SEPTAGE GENERATION BY STATE*

State	M^3/Yr	Gal Yr (Millions)	State	M^3/Yr	Gal/Yr (Millions)
AL	0.36	96.3	MT	0.07	18.5
AK	0.02	4.7	NE	0.10	26.3
AZ	0.11	28.6	NV	0.02	5.5
AR	0.21	55.1	NH	0.10	27.3
CA	0.81	213.3	NJ	0.38	101.1
CO	0.11	28.3	NM	0.06	16.4
CT	0.34	88.6	NY	1.22	322.3
DE	0.00	1.0	NC	0.65	171.9
DC	0.00	0.11	ND	0.05	13.3
FL	0.89	234.6	OH	0.74	194.9
GA	0.45	118.6	OK	0.19	50.8
HI	0.05	12.6	OR	0.26	69.0
ID	0.09	23.3	PA	0.93	246.3
IL	0.52	138.7	RI	0.10	26.9
IN	0.56	147.4	SC	0.32	83.6
IA	0.24	64.5	SD	0.06	15.6
KS	0.16	41.0	TN	0.43	114.3
KY	0.30	78.2	TX	0.62	163.6
LA	0.27	71.9	UT	0.05	12.3
ME	0.13	35.1	VT	0.06	17.1
MD	0.23	60.9	VA	0.39	102.1
MA	0.46	122.6	WA	0.38	101.0
MI	0.80	211.9	WV	0.18	46.8
MN	0.29	76.9	WI	0.35	92.9
MS	0.20	52.3	WY	0.02	5.8
MO	0.34	89.8			
			Total U. S.	15.67	4,141.91
			Ter. (Avail.) PR	0.11	28.15
			Total U.S. and Ter. (Avail.)	15.78	4,170.06

*Based on pumping a 1,000 gal septic tank every 4 years.

daily hours, the number of days of weekly operation, and the home occupancy pattern (primary or secondary home), are influencing factors in delivery variation. (10) Southern climatic conditions seem to attenuate the estimated pumpout frequency, since higher year round temperatures increase the organic material digestion rates in the septic tank.

Septage generation is usually greater in the warmer seasons than during the cooler time periods of the year. Ice and snow cover, and frozen ground limit accessibility to the septic tank, and odors indicating a failed system are frequently absent during this period, all contributing to lower pumpout frequency in northern climates during winter. Figure 4 is indicative of this septage loading pattern. These data were taken from the Lebanon, OH STP for the year 1972.

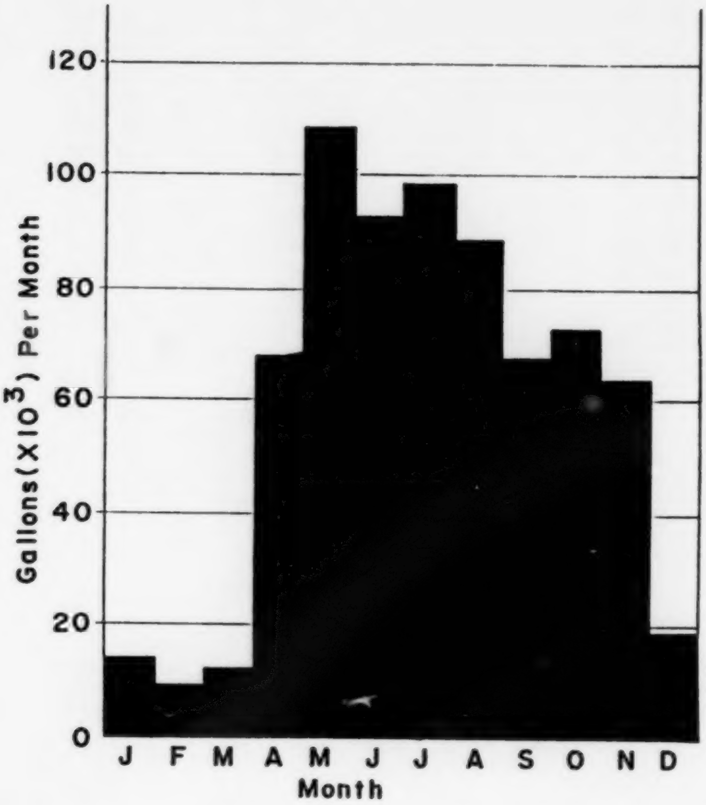

Figure 4. Septage loading pattern, Lebanon, OH STP.

SEPTAGE CHARACTERISTICS

Septage is a highly variable anaerobic slurry whose characteristics include large quantities of grit and grease, a highly offensive odor, the ability to foam, poor settling and dewatering characteristics, high solids and organic content, and often an accumulation of heavy metals. Table 4 presents septage characterization data compiled by the U. S. EPA's Municipal Environmental Research Laboratory in Cincinnati, OH compared to extreme values reported in the literature.

Physical and Chemical Properties

Graner (9) reports septage characteristics in Nassau and Suffolk counties similar to medium to strong municipal wastewater, while Goodenow (11) in Maine found some samples with total and SS over 130,000 mg/l and 93,000 mg/l, respectively. Tilsworth (12) obtained some septage samples with BOD_5 over 78,000 mg/l and COD's over 700,000 mg/l in Alaska. The EPA's mean concentrations are good indicators of septage concentration when compared to the data of most researchers.

A significant variability in septage characteristics has been reported by most investigators. The cause of the variability may be the result of a combination of many undocumented factors, including user habits, tank design, and sampling procedure. Pumping equipment and hauler practices, as described in the next section, are also elements. Time of the year, as relates to seasonal groundwater, may affect septage strength. Some haulers on Long Island, for example, report they have pumped out 1,500 to 2,000 gal of septage from a 1,000 gal septic tank, the excess being groundwater pulled in from the soil absorption system or through cracks or holes in the septic tank. The use of garbage grinders in kitchens was observed to result in an increased rate of scum accumulation. (6) The age of septage (time between pumpings) was also found to be important. Feng (13) reported the levels of BOD_5, SS, and NH_3-N varied with age in Amherst, MA septage, as anaerobic decomposition partially liquifies and gasifies the solids.

Characteristics of septage from other than domestic sources have not been reported in sufficient detail to be analyzed. These other residuals may be waste products of laundries, industries, restaurants, or institutions. Any facility treating these wastes should have an adequate sampling and screening program to determine their characteristics prior to truck unloading thereby avoiding serious plant upsets from unanticipated constituents.

TABLE 4. SEPTAGE CHARACTERISTICS
(all values in mg/l except for where noted.)

Parameter	EPA Mean Concentration	Minimum Reported	Maximum Reported	Variability*
TS	38,800	1,132(9)	130,475(11)	115
TVS	25,300	4,500(96)	71,402(11)	16
TSS	13,300	310(12)	93,378(11)	301
VSS	8,700	3,660(96)	51,500(16)	14
BOD_5	5,000	440(9)	78,600(12)	179
COD	42,900	1,500(12)	703,000(12)	469
TOC	9,900	1,316(14)	96,000(15)	73
TKN	680	66(14)	1,900(96)	29
NH_3-N	160	6(14)	380(15)	63
NO_2-N	----	0.1(15)	1.3(15)	13
NO_3-N	----	0.1(15)	11(17)	110
Total P	250	20(96)	760(14)	38
PO_4	----	10(96)	170(96)	17
Alkalinity	----	522(12)	4,190(12)	8
Grease	9,100	604(14)	23,368(14)	39
pH (units)	6 - 9	1.5(9)	12.6(9)	8
LAS	160	110(14)	200(14)	2

* Values represent ratio of maximum to minimum.

Metals

The U. S. EPA has addressed the question of septage metal concentration in studies at Lebanon, OH and Blue Plains in Washington, DC. Assuming all samples were from domestic sources, metal contamination of septage probably resulted from one of three sources: 1) household chemicals which contained trace concentrations of heavy metals that adsorb to solids and show increasing concentrations with time, 2) contamination of septage in hauler trucks from a previous industrial waste load, or 3) leaching of metal (particularly cadmium (Cd) associated with zinc (Zi) in galvanized piping) from household piping and joints. Table 5 shows the results of this testing, showing concentration, minimum and maximum observed values, and variability of twelve metals. If the value for mercury (Hg) is deleted from the variability column, then the order of variability for chemical parameters is very close to the metals variability.

In Table 6, the geometric mean heavy metal content of residential septage from Lebanon, OH and from Blue Plains, STP near Washington, DC, is compared to geometric means found in raw and digested sludge from American, Danish, and Swedish STPs on a mg/kg dry weight basis. From this table it is noted that septage contains significantly lower concentrations of heavy metal than does municipal treatment plant sludge. (14) This level of metal content is of significance when consideration is given to septage application to the land. Significance of metal toxicity in the land disposal mode is discussed in Section 4.

Bacteriological Characteristics

Bacteriologically, septage contains predominantly gram-negative nonlactose fermenters. (5) Many of these microorganisms, such as Pseudomonas, which are considered aerobic, have been found in septic tanks. Numerous obligate anaerobes are present, but only spore-forming types, including Clostridium lituseburence and Clostridium perfringens, have been recovered. Calabro was unsuccessful at isolating nonspore-forming obligate anaerobes because species such as Bacteriodes are exceedingly oxygen sensitive, and the septic tank pumping operation may have exposed them to incident oxygen. Figure 5 shows the comparative enumeration of specific types of microorganisms from 12 septage and septic tank sewage samples, with 95% confidence limits. Septic tank sewage samples were taken from the inlet end of a functioning septic tank at a depth of 61 to 91 cm (2 to 4 ft). The standard plate count (SPC) per ml was determined after 48 hours of incubation under aerobic and anaerobic conditions at 24°C. When the septic tank is pumped, mixing of the bottom sludge, intermediate wastewater and upper layer of scum occurs. The presence of aerobic organisms in a septic tank can be explained by either the dissolved oxygen of the incoming sewage providing sufficient oxygen to allow limited aerobic growth or chemostatic action by displacement of effluent by the influent furnishing a relatively constant number of aerobic microorganisms. (18) It is therefore fortunate that Pseudomonas and other similar aerobic bacteria are found in the septic tank, as they are capable of lipid and detergent degradation.

Calabro estimated the gross relative stability of septage, septic tank effluent and domestic wastewater using methylene blue as a redox indicator of biological activity. Septage samples changed color in 5 hours, septic tank effluent between 6 and 21 hours, and raw domestic sewage between 17 and 21 hours. (18)

While information on the presence and survival of viruses in septic tank effluents was reported by many investigators (Senault, Foligate, Laurienant, and Martin, 1962, and numerous publications by the University of Wisconsin Small Scale Waste Management Project), little is reported on virus, bacteriophage, ovum and cyst identication and survival in septage.

TABLE 5. SEPTAGE METAL CONCENTRATIONS
(all values in mg/l)

Metal	EPA mean Concentration	Minimum Reported	Maximum Reported	Variability*
Al	48	2.00(14)	200.0(14)	100
As	0.16	0.03(14)	0.05(14)	17
Cd	0.71	0.05(14)	10.8(14)	216
Cr	1.1	0.3(14)	3.0(15)	10
Cu	6.4	0.3(15)	34.0(14)	113
Fe	200.0	3.0(14)	750.0(14)	250
Hg	0.28	0.0002(14)	4.0(14)	20,000
Mn	5.0	0.5(14)	32.0(14)	64
Ni	0.9	0.2(14)	28.0(15)	140
Pb	8.4	1.5(14)	31.0(14)	21
Se	0.1	0.02(14)	0.3(14)	15
Zn	49.0	33.0(15)	153.0(14)	5

* Values represent ratio of maximum to minimum.

TABLE 6. HEAVY METAL CONTENT OF SEPTAGE AND MUNICIPAL SLUDGE (14)
(mg/kg)

	Lebanon, OH		Municipal Sludge		
Metal	Septage	Salotto	Other U. S.	Denmark	Sweden
Cd	5.5	43	69	10	9.8
Cr	21.0	1,050	840	110	170
Cu	28.1	1,270	960	340	670
Hg	0.24	6.5	28	7.8	5.8
Mn	106	475	400	350	400
Ni	28.5	530	240	37	65
Zn	1,280	2,900	2,600	2,600	1,900

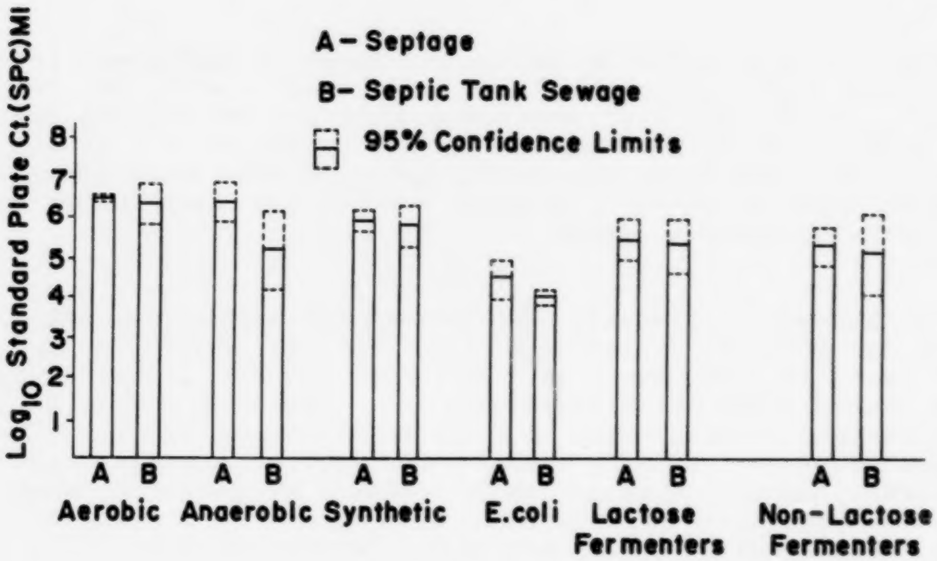

Figure 5. Comparative enumeration of specific types of microorganisms with 95% confidence limits.

SECTION 5

PRESENT PRACTICE

SEPTAGE HAULER

The hauler is known by different names in different regions: "scavenger waste hauler", "septic tank cleaner", or "septage hauler". No matter what the name, this person usually operates as a small independent business person owning 1 to 3 trucks, although firms having as many as 20 vehicles have been identified. There is approximately 1 septage hauler for each 3,000 septic tanks on a nationwide basis.

The hauler is fiercely independent by nature and often secretive in methods, practices, and records, which is why many state agencies repeatedly have had poor success in obtaining vitally needed planning information from them. Although haulers' organizations exist, they are local in character and have no national representation. Members of haulers' organizations have repeatedly tried to raise their status by pressing state and local agencies to require both licensing and qualifying examinations. These efforts have met with limited success.

In some areas of the country, unscrupulous haulers, mostly transients, known as "floaters" or "drifters", cause problems when they dump septage loads in unapproved or potentially hazardous sites, such as streams or roadside ditches. In many areas, the few floaters have given the approximately 4,000 honest haulers a stigma.

Equipment

Discussions with state and local regulatory agencies and private haulers about hauler equipment resulted in a basic agreement on minimum requirements as well as preferable equipment. Much of the equipment used in the field today is functional, but will not meet certain state requirements, such as Oregon's Sewage Disposal Service regulation. Recommended minimum requirements and preferred equipment for trucks, valves, hoses, pumps, and other equipment are listed below.

Trucks--

Minimum Requirements-- Hauler trucks should provide a watertight metal enclosure, with at least 3.8 m^3 (1,000 gal) capacity, which is usually the nominal size septic tank presently being installed. Tanks should have an access port for periodic inspection and maintenance. A device for determining the quantity of liquid in the truck, such as a sight gauge, should be included. On each side of the tank there should be a painted sign in contrasting colors, at least 7.6 cm (3 in) high, disclosing the business name, address, capacity of the truck, and a disclaimer that the truck is to be used for cleaning residential septic tanks and not for industrial wastes. Annual or more frequent inspections by the appropriate authority, usually either the state or local health department, should determine if the trucks are leakproof and in a sanitary condition. A pressurized washwater tank with disinfectant and cleanup implements should be on each truck.

Preferred Equipment-- Many haulers are advocates of larger capacity trucks, since fewer non-revenue generating runs must be made to the disposal site. A nonleaking rear door on the tank has been reported as useful in recoating, repairing, and servicing the tank. Other desirable components include a catwalk and guard rail with hose racks.

Valves--

Trucks should have drip-tight gravity drainage valves that can be safety locked during transportation and storage. Spreader type gates are not recommended.

Pumps--

Minimum Requirements-- Pumping equipment on hauler trucks should be able to provide at least a 3.2 m (15 ft) suction lift with reversible flow. Some haulers prefer having their pumps pull a vacuum on the truck's tank. In this case, a vacuum pump or blower with a water trap to prevent septage aerosol dispersion is provided. A high level automatic shutoff control should be included to avoid spillage and associated aesthetic and health hazards. Other haulers prefer an in-line, self-priming sewage pump with a high net positive suction head (NPSH) capacity. These open impeller or recessed impeller pumps should have the ability to pump heavy slurries with rocks or large solids that are frequently encountered. Annual inspection should include verification that no leaking is occuring through the pump diaphragm or packing glands. Minimum pump capacity should be about 1,500 l (400 gal) per minute.

Preferred Equipment-- Air exhausts on vacuum pumps or air outlets on in-line pumps should have an activated carbon filter or other suitable devices for odor control. Combination vacuum/pressure gauges are useful in determining system performance. When in-line pumps are used, consideration should be given to materials for impellers and other internal parts which are superior in abrasion resistance to those commonly provided. Series pumping with twin pumps are provided by some tank truck manufacturers for use when heavy septage slurries are encountered. Some pumps used have capacities up to 4,500 l per minute (1,200 gpm).

Hoses --

Hoses used in pumping septage should be a minimum 7.6 cm (3 in) diameter. High pressure black rubber is expensive but works well. Spirally wound flexible vacuum tubing is less expensive, but haulers tend not to like this material because frequent breakage and subsequent spills result at the couplings. Hoses should be capable of being drained, capped, and stored without spilling their contents. Discharge nozzles on the hauler trucks should have either a cam lock quick coupling or threaded screw cap and should be sealed when not in use. Haulers normally carry a minimum of 100 to 150 ft of hose.

Other Equipment --

This heading includes equipment for breaking up the scum layer, such as a long-handled shovel, rake, and manhole "spoon". Probes are often necessary in locating buried septic tanks. A trash container with close-fitting lid should be carried to hold dirt, which should be scooped up if septage is spilled on it. (19)

Hauler Practices

Pumping --

The strength of septage is often dependent on the mode of pumpout a hauler uses. A weak, in-line pump will leave most of the heavy matter in the tank, while a pumper who draws a high vacuum on his tank and then opens his valve quickly will draw almost all the heavy sludge, grit and scum from a tank. Most haulers are cognizant of the need to leave a small amount of septage in the tank as a starter, or seed material, for digestion of future wastes. Most haulers report they leave from 5 to 10 cm (2 to 4 in) of sludge material in the tank. Washing down and disinfecting a tank is not recommended.

The pumping procedure requires the removal of almost all accumulated bottom sludge and all top scum mat from the septic tank. The NEIWPCC recommends lowering the liquid level sufficiently below the outlet to prevent sludge and scum from entering the distribution system before breaking up the scum mat for pumping. A long-handled tool should be used to pull sections of scum from far ends of the tank toward the pumpout hose. Following the scum removal step, the bottom sludge and septic tank wastewater should be pumped out. It may be necessary to backflush the tank by reversing the suction of the vacuum pump to force loose the accumulated solids from the bottom of the tank. After the required amount of septage has been pumped, the hauler should inspect the inlet and outlet baffles and pipes for signs of clogging or deterioration.

At the end of each workday, equipment and the exterior of trucks should be cleaned and the washwaters disposed of as if they were sewage.

Maintaining the Septic System--

A periodic, scheduled pumping, to prevent premature clogging of the leaching field, is generally required to properly maintain a septic system. At each 3 or 6 month interval, the homeowner should check the scum and sludge accumulation level in the tank. The Manual of Septic Tank Practices recommends pumping the septic tank when certain levels are reached, depending on tank geometry. (5)

Many haulers may recommend septic tank maintenance products to the homeowner. However, the Manual of Septic Tank Practice reports no product has proved to be of advantage in properly controlled tests. Many haulers report that the addition of a 2 lb box of baking soda into the homeowner's drain each week will provide significant buffering to the septic tank, keeping the pH in the 6 to 8 range and resulting in less of a hard, crusty scum layer. Other chemical additions or treatments, such as acid or alkali treatments, may be, at best, of no value. Sometimes temporary relief is seen, followed frequently by a damaged soil structure and accelerated clogging. These products are not recommended.

Enzyme products and live microbial cultures are not necessary in properly functioning septic systems, and most should be considered of no value until proven otherwise. Many haulers and various state agencies in Ohio, Virginia, and Michigan have used a liquid suspension of live microorganisms to reduce the quantity of grease and scum buildup and grease-caused clogging in leaching fields. (20)

Before an individual decides to use any product in a septic tank, a check with the local health department is highly recommended.

Disposal Sites-- In most states, haulers have the option of disposing of domestic septage in an approved, privately owned facility or in a publicly owned facility. A privately owned site is usually a land-spreading site or disposal lagoon. The publicly owned facility may be identical to the one privately owned or may be a specially designed septage treatment works, sanitary landfill (SLF), or wastewater treatment facility.

Unloading-- When a hauler wishes to discharge a load at the disposal site, the truck's gravity drain valve is opened and the contents generally drained in 10 to 20 minutes, depending on the size of the tank. In order to reduce unloading time, haulers often pressurize their tanks, open drain valves, and literally explode the septage out of their trucks. This practice often results in splattered septage and the release of noxious odors, and should be curtailed in all cases.

pH Adjustment-- When a hauler discharges at a treatment facility, a sample often is taken and the pH checked. If the pH is outside the acceptable range, the hauler must find another suitable disposal site. Several haulers have overcome this by chemical addition to raise or lower pH with recirculation of the contents by self-contained pumps, or they have storage tanks at their base location (John Schultz, Columbia Processors Co-Op, Portland, OR) to blend several septage loads until an acceptable pH is obtained.

One hauler in Massachusetts (John McNeil, Duxbury, MA) has tried lime addition to his tanker truck for pH control and waste stabilization. A 45 kg (100 lb) bag of lime added to a 7,500 l (2,000 gal) truck prior to pumping did not stabilize the contents, proved difficult to mix into a slurry, tended to cake up on the inside of the truck, and cemented the outlet. This practice is not recommended unless the tank and associated pumping equipment has been designed for this function. Soda ash and baking soda were found to be easier to handle, but the amounts required are costly.

Hauler Comments

Some of the more frequently encountered recommendations and criticisms offered by the hauler community are listed in brief form below. Most comments tend to be general in nature and are divided into 3 basic categories. The first category deals with septic system design and construction. The second class lists desired improvements in management technique, particularly regulatory agency, while the last group of suggestions calls for specific educational programs.

Design
- Poor design of septic tank openings
- Tank covers too heavy
- Tank openings difficult to locate
- Tanks should have better access for cleaning
- Tanks should be redesigned for easier cleaning
- Poor location to outlet "T" for cleaning
- Restrict fiberglass tanks to areas well above groundwater
- Restrict use of steel tanks
- Tighter construction joints in tanks and piping

Management
- More detailed initial Health Department inspection during site selection and construction
- Prefer area-wide tax on disposal rather than fees
- Correct lack of contingency disposal plans when small plant normally employed for disposal are closed
- Need exists for hauler spare parts distribution network
- Licensing and registering haulers by personal examination

Education
- Desire more information on regulatory agency disposal site criteria
- Desire a National Haulers Association as a means of exchanging hauling and disposal information
- Decry the unavailability of specialized information of Health Department inspectors, which prevents haulers from defending inequitable applications of existing regulations
- Desire an intensive education campaign for homeowners which would include the following basic points promoting existing system longevity:

1. Reduce water usage
2. Reduce use of garbage grinders
3. Proper placement of disposable diapers and sanitary napkins
4. Buffering of system by weekly addition of baking soda, if local testing proves beneficial

Hauler Charges

An estimate (shown in Table 7) was performed to determine a reasonable charge a homeowner could expect to pay for having a 3.79 m^3 (1,000 gal) septic tank cleaned, assuming the tank is easily accessible and no additional work was needed. It was based on a 25 km (15 mile) haul to the disposal point, 2 hours travel time per load, vehicle depreciation and insurance of $4,108 per year, and estimated wages. Depending on the level of profit and a disposal cost not exceeding $15, a reasonable charge would be in the range of $25 to $70, 1976 prices.

As of 1976, fees charged to homeowners ranged from a low of $20 to $25 per 3.8 m^3 (1,000 gal) in parts of Long Island to around $100 per 3.8 m^3 (1,000 gal) in areas of New Jersey, Connecticut, and Oregon. Rural areas in New England had slightly lower charges, $25 to $40 per 3.8 m^3 (1,000 gal), while in most areas of the rest of the country, charges were in the range of $40 to $60 per 3.8 m^3 (1,000 gal). These charges are dependent on the distance from the septic tank to the disposal point (especially pronounced if over 15 miles) and the disposal fee charged.

REGULATORY CONTROL

Basis for Regulations and Legislation

Regulatory and public health officials recognize that protection of the public health is of paramount importance. When combined with the recently accepted public mandate for maintenance and improvement of environmental quality, they acknowledge that the achievement of these goals can be furthered by the enactment and enforcement of rules and regulations governing septic system construction and maintenance practices by various bodies of government, ranging from local units to county, region, or state.

Existing Regulations

Regulatory decisions in the septage management area have far reaching effects, from both economic and environmental standpoints. These decisions may affect licensing requirements, hauling equipment used, pretreatment requirements, allowable disposal practices, and regulation enforcement.

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4. Buffering of system by weekly addition of baking soda, if local testing proves beneficial

TABLE 7. ESTIMATED HAULER CHARGES

Estimated travel costs of septage hauler truck and charge homeowner might pay for cleaning 3.8 m^3 (1,000 gal) septic tank with hauling 1 way travel distance of 25 Km (15 miles) (21)

1.	Assumptions: 1500 gal (5.7 m^3) truck, 7 yr life, initial cost \$20,000, travels 40,000 Km (25,000 miles) per yr. Capital recovery factor (0.2054) x 20,000 = \$4,108 per yr. $\frac{4108}{40,000}$ = 0.103/Km 50 Km round trip	\$ 5.15
2.	Fuel and lubricants \$0.069/Km x 50 Km	3.44
3.	Maintenance and insurance \$0.038/Km x 50 Km	1.88
4.*	Labor at \$15.00/hr x 2 hours	30.00
5.	Other costs 0.033/Km x 50 Km	1.63
6.	Disposal cost at \$15.00/3.8 m^3	15.00
		\$57.10

*Profit included in Labor Charge.

Permit Requirements--

Most states have some form of permit or licensing requirements for the septic tank cleaner. States usually license the hauler company, while a smaller number license each truck separately. Fees usually range from \$50 to \$500 per company, with truck fees varying from nominal charges to several hundred dollars per truck. A smaller number of states leave permit requirements up to the county or municipal authorities. Many states have concurrent registration codes with county or local government agencies. Connecticut is the only state that has a registration act which certifies individuals as competent on a professional basis as determined from education and examination standards. Most existing licensing requirements therefore act as identifiers and revenue generation instruments.

Equipment Requirements--

Few states have specific requirements for type, construction, maintenance, operation, and periodic inspection of septage pumping and transportation equiment. Many states did, however, cover this area in a general way by the use of phrases such as "sanitary procedures" or "shall not create a health hazard". Delaware, Illinois, Massachusetts, and Oregon detailed certain requirements, but compliance is in direct relationship to the policing effort of the responsible agency. Commonly used and preferred equipment is detailed in the previous section dealing with Haulers.

Disposal Requirements--

Most states require a hauler to submit disposal plans and have them approved prior to use. Recommended disposal practices were found to vary from state to state, but little actual variation was found on a nationwide basis. Regional factors which influence disposal options such as precipitation, temperature, and soils seldom entered into regulatory decisions. For example, septage is allowed to be placed in sanitary landfills in rainfall-abundant western Washington state.

Sewage treatment plants and sanitary sewers are usually allowed as disposal points if plant capacity is sufficient and the plant's effluent will not be degraded beyond permit requirements. Land disposal and SLF application are also typically permitted if public health and ground and surface waters are protected.

Reporting Requirements--

Few states require haulers to keep or submit records. These records should include the septic tank owner's name, address, volume of tank, condition of tank, location on property, date last pumped, and point of disposal. Those states that do have some form of reporting have encountered very poor response. These background data are useful in preparing disposal plans.

Contingency Requirements--

No state studied had any requirements for backup or contingencies in the event that the normal disposal means (such as a wastewater treatment facility) was not able to accept the wastes as generated.

The matrix in Table 8 describes some of the above listed practices in many states where septage disposal is a significant problem.

TABLE 8. EXISTING STATE SEPTAGE REGULATIONS

State	Hauling Permit	Equipment	Septage Disposal	Comments
AL	County Health Officer licenses hauler co.		1. Approval of local DPH 2. Sanitary sewers 3. Method of disposal reviewed by county health officer	
AK	County licenses hauler co.		Dept. of Environmental Conservation (DEC) requires review	1. Reluctant to allow septage to treatment plant because of upsets 2. DEC may require pretreatment before STP
AZ	1. County licenses hauler co. 2. State Dept. of Health licenses all operators	1. Container to be leakproof and flytight 2. Dept. of Health licenses all trucks	County Health Dept. may approve: 1. Community sewer system 2. Burial 3. Open dumping	
CA	Regional Water Quality Control Board (RWQCB) licenses haulers	RWQCB licenses all trucks	RWQCB may approve: 1. STP 2. Class II sanitary landfill a. Surface drainage b. Leachate controlled c. 0.0115-0.184 m^3/m^3 (25 - 40 gal/cy) of refuse in Bay area	1. Penalties for violations are $100/30 days and revoke license 2. Record loads and disposal and submit reports. 3.20% to STP, 80% to land
CO	Local Board of Health licenses haulers		1. Municipalities have ordinances on disposal 2. State Division of Water Resources prefers septage to be placed upstream of STP 3. Land spreading regulated by counties	
CT	Hauler licenses by State Dept. of Health	1. Trucks bear name of co. 2. Watertight vehicles in a clean condition	1. Municipalities responsible for providing disposal facility - Most don't 2. Local Health Dept. site permit needed if disposal is offsite of septic tank owner 3. State DEP closing unacceptable sites and emphasizing new anaerobic-aerobic digestion lagoons	1. Pumper strikes and other actions forced one town to provide disposal sites 2. Violation - $100/30 days
DE	State permits for haulers dumping into sewer or STP	1. Tanks watertight 2. Hoses leakproof 3. Receptacles portable 4. Automatic shutoff valves for pumping and discharge hoses	1. Two of three counties go to STP 2. Other county "plows in" - road setback 300' 3. Discharge not pollute water course, water supply, bathing	Sufficient capacity at STP necessary to treat septage
FL	State licenses hauler, but inspected and approved by local office	Inspected and approved by local office	1. Sites inspected by state 2. Local codes may dictate disposal practice in area 3. State prefers STP, not landfill	Revoke or deny future hauler license for violations

(continued)

TABLE 8. (continued)

State	Hauling Permit	Equipment	Septage Disposal	Comments
IL	State Health Dept. licenses haulers - county may license too	State Health Dept. has regulations for: 1. Tank 2. Vacuum pump 3. Hose 4. Nozzle 5. Self-rinsing	1. IEPA and State Health Dept. requires permits a. Application to farmland b. Landfill c. STP d. Sludge drying beds 2. Local codes for dumping in sewer system	1. OK to dump wastes to sanitary sewers if they don't harm STP 2. Hauler must file disposal plan with Health Dept. 3. Local codes may be more strict under Home Rule power
IN	State Board of Health licenses hauler	State Board of Health licenses vehicles	1. State prefers STP subject to municipal approval 2. Written approval for landfill as contingency only 3. Burial in private property with owner's approval	1. Minimum fine for violation $25 - $100 2. Pumpers must be bonded
KS	County Health Depts. licenses hauler		1. Public sanitary sewer 2. Plow under in cropland 3. Sanitary landfill 4. Dewatering by vacuum filtration	
KY	State licenses hauler after local Health Dept.	State inspects equipment and license	Local Health Dept. enforcement: 1. Municipal sewers 2. Burial 200 yards from residences, roads 3. Property served should be left in sanitary condition	
ME	Dept. of Environmental Protection (DEP) issues license plates		Disposal is municipal responsibility subject to DEP approval, except STP. Recommended practices: 1. STP 2. Land spreading 3. Spray irrigation 4. Lagooning Not recommended: 1. Landfills 2. Composting	Violations bring $100 maximum fine
MD	Permit required by State Dept. of Health and Mental Hygiene (DHMH)	Specific guidelines for size of truck	1. DHMH must approve all sites in writing 2. Setback 200' from any highway	
MA	1. State DPH 2. Board of Health 3. Local Board of Health	Inspection and approval by local Board of Health 1. Tank 2. Hose 3. Pump 4. Venting 5. Drying and burial - local Board of Health 6. New seepage lagoon regulations	1. Local Board of Health approval required from town pumped from and town disposed in 2. Sanitary sewer - approval by local authority	1. Minimum fines for violations: $10 - $50 2. Confusing and redundant local laws requiring registering with Boards of Health for each municipality septage is transported through, even if on state or interstate highway
MI	DNR licenses haulers and County Health Dept. responsible for surveillance	1. Separate equipment 2. Display sign on vehicle	1. State prefers STP but need local approval 2. Land spreading permitted: a. 1,000 foot from property b. Written approval of owner and local Health Dept.	Violations bring: a. $5,000 - $25,000 plus jail b. Revoke license

(continued)

TABLE 8. (continued)

State	Hauling Permit	Equipment	Septage Disposal	Comments
MN	Permit required from Division of Public Health Services and local community	Regulations on vehicle structure and equipment - inspection by State		
MO	No statewide rules. Responsibility of municipalities			
NE	No permit requirements		1. Local Health Depts. regulate disposal in some areas 2. Shallow trench disposal preferable	State laws recently defeated
ND	Permit required from local health officer	Equipment requires inspection and approval of local health officer	1. Spread on land 2. Burial a. 1,000' setback b. No surface or groundwater contamination c. No contact with livestock and food producing land 3. Sanitary sewer	
NH	Permit required from Division of Public Health Services (DPHS)	Operator files statement on transportation and means of septage removal	Disposal site reviewed by DPHS	Violations bring: 1. $100 or more in fines or 60 days in jail 2. Permit revoked
NJ	Bureau of Solid Wastes Management licenses vehicles. Landfills pay annual registration fee	Annual inspection	1. Sanitary landfill loading at 0.0046 m^3/m^3 (10 gal/cy) solid waste 2. Land disposal also used 3. STP not recommended	Insufficient statewide disposal area available caused hauler demonstrations
NY	DEC and County Health Board require permits. Towns or villages may require permits	Display of permit on vehicle	1. STP owner's permission filed with hauler permit 2. Land disposal sites to be approved by regional DEC and County Health Dept. 3. Special septage treatment plants encouraged 4. DEC rates landfills as last disposal option	1. Haulers responsible for annual report on collection and disposal volumes 2. Different level of government have different regulations for disposal
NC	Permit required from County Health Director		1. Sanitary sewers 2. Landfills 3. Burials	
OH	Dept. of Health requires permit	Local requirements only	1. Land spreading on farmland most common 2. STP 3. Landfills	
OR	1. Dept. of Environmental Quality (DEQ) requires permit 2. Vehicle registered with State Board of Health 3. Permit required from local health officer	1. Hauler files description of equipment 2. Division of Health inspects for: a. Tank b. Hose c. Pump d. Discharge nozzle e. Cleanup facility	1. Disposal site to be approved by DEQ 2. DEQ recommends: a. STP with two holding tanks b. Non-overflow lagoons c. Land disposal on fields without crops d. Plowed under if near habitation	1. Hauler must maintain origin and disposal records 2. Violations: $1,000 or revoke license

(continued)

TABLE 8. (continued)

State	Hauling Permit	Equipment	Septage Disposal	Comments
PA	County Health Depts. may require licenses	Varies by county	1. State Dept. of Environmental Regulation approved hauler disposal sites 2. State recommends STP but land disposal most frequent 3. Landfills, lagoons, and trenches also permitted	1. Lack of statewide regulation hampers management (5 of 62 counties have regulations) 2. 90 - 95% septage to land, 5 - 10% to STP
RI	State Dept. of Health requires permit		1. Disposal site to be approved by Dept. of Health 2. Disposal in STP most common	
TN	Dept. of Public Health requires permit		Local Health Depts. have regulations for disposal	Regulations being developed to comply with new act
TX	Dept. of Public Health recommends licensing and regulatory practices to local authorities		1. Disposal site set back 300' from highway unless buried or treated 2. Dept. of Public Health encourages disposal to STP	
VT	No state regulations - Local Health Dept. option of licensing		1. Septage prohibited from landfills 2. Local health officer approves land disposal a. Land spreading b. Disposal trenches 3. Few STPs accept septage	1. Little cooperation among units of government - No overall plan. State officials estimate percentage disposal as follows: 15% STP 45% land 40% illegal
VA	No statewide regulations		State Water Control Board requires septage treatment systems to be approved as industrial waste treatment sites. Options include: a. Lagooning b. Wet air oxidation c. Chemical treatment d. STP e. Land disposal	More local control anticipated
WA	Permit required from local Health Dept. with secondary responsibilties shared by Dept. of Ecology and Dept. of Social and Health	Local Boards of Health set standards on vehicles, equipment, and operation	1. Disposal site to be approved by local health officer 2. Preferred disposal options include: a. STP b. Surface spreading c. Anaerobic lagoons d. Sanitary landfills	Additional regulations in preparation
WV		Dept. of Public Health requires equipment that can flush, clean, and deodorize septic tanks	1. Disposal in sewer or STP with local approval 2. Incineration acceptable 3. Burial requires approval of State Dept. of Health	

Suggested Regulations

Ideally, a state regulatory program should address the maintenance and repair of septic tanks, and the licensing of haulers, as well as provide for rational disposal alternatives. Such a program would eliminate gross local code differences and should include the following items.

I. User-Related Regulations

1. Users should be required to have septic systems inspected and pumped, if necessary, on a predetermined schedule.

2. Since the average American home is sold once every 7 years, a correlative regulation could require each septic system to be inspected and pumped, if necessary, before transfer of title can take place.

II. Hauler-Related Regulations

1. Equalize local permit requirements by a statewide hauler permit program.

2. Register all hauling vehicles.

3. Certify individual haulers by examination and levy uniform statewide annual fee.

4. Establish hauler truck specifications.

5. Inspect all trucks annually.

6. Prohibit industrial waste hauling trucks from pumping out domestic tanks.

7. Require haulers to maintain accurate files of the date system serviced, volume transported, disposal site utilized, and report results annually.

III. Disposal-Related Regulations

1. Establish statewide program requiring municipalities or regional governments to designate disposal facilities and alternates in their area. This program would eliminate the restrictive geographical area of individual governmental units, yet be responsive to local needs. Enactment might be similar to Maine's Regional Refuse Act.

2. Establish user fees for public disposal facilities based on capital and operation and maintenance costs. Costs could be recovered through general taxation of septic tank users or a combination of fees and taxation. Disposal fee should be kept low to discourage unregulated (illegal) disposal practices. Taxation rebate consideration should be applicable to the hauler who disposes of septage privately.

3. Design and construction of disposal facilities should be approved by state prior to use.

4. Require disposal site to maintain files on volumes and sources of septage received. A sample should be taken of each load for identification purposes if the area has history of problems with industrial wastes.

Less strict or less comprehensive regulations than those listed above might be envisioned in areas with a smaller population base served by onsite septic systems and relatively few problems.

SECTION 6

SEPTAGE DISPOSAL ALTERNATIVES

LAND DISPOSAL CRITERIA

Septage disposal on the land can include surface spreading and sub-surface injection, spray irrigation, trench and fill techniques, lagooning, and disposal in SLFs. Common requirements in all land disposal alternatives are analyses of soil characteristics, seasonal groundwater levels, neighboring land use, groundwater and surface water protection and monitoring, climatological conditions, and site protection such as signs and fencing.

Land spreading requires a knowledge of land slopes, often limited to 8%, and runoff conditions. Other requirements may include storage facilities for times when land application is inadvisable, crop management techniques, odor control procedures, and loading criteria. Loading criteria generally are determined by agricultural considerations, which result in nitrogen (N) and heavy metal loading rate limitations.

Loading Factors

Nitrogen--
In most agricultural areas, available existing nitrogen is far below levels needed for optimum crop yield. As a result, artificial sources of nitrogen are generally added, such as commercial fertilizer. Nitrogen is available as a plant nutrient in the form of the ammonium ion which is retained on negatively charged soil particles. (22) Septage is rich in available ammonia, about 25% of the total 0.6 to 1.0 kg_N/m^3 (5 to 8 lb $_N$/1,000 gal) occuring in this form. Soil bacteria will transform NH_4-N to NO_3-N, but much of this N may not be available for plant use if hydraulic loadings cause the highly soluble NO_3-N to be leached below the plant root zone. Nitrogen may also be lost if poor drainage conditions exist, causing ponding which provides anaerobic conditions and conversion of nitrate to N gas.

Health aspects dictate that N be applied at rates less than or equal to plant N uptake requirements, since excess nitrate formation could contaminate groundwater or surface water through leaching or runoff. Since it is generally recognized that NO_3-N concentrations above 10 mg/l in drinking water may cause health problems, particularly infant methemoglobinemia (nitrate cyanosis), concern is justified. Nitrate pollution in surface waters also can lead to eutrophication, or premature aging of lakes and streams.

The State of Maine has reported, in its Guidelines for Septic Tank Sludge Disposal on the Land, (23) that a loading criteria of 585 m^3/ha/yr (62,500 gal/acre/yr) on well-drained soils and 351 m^3 ha/yr (37,500 gal/acre/yr) on moderately well drained soils should not result in pollution caused by excess N. These loadings result in N application rates of 560 kg/ha/yr (500 lb/acre/yr) and 336 kg/ha/yr (300 lb/acre/yr), respectively. Maine officials report that monitoring wells at sites that follow these criteria show no signs of groundwater pollution.

Phosphorous and Potassium--

Both phosphorus (P) and potassium (K) are basic requirements for plant growth. Land application of septage usually results in P loadings in excess of plant requirements, while K deficiencies will result at the same dosages. Both elements, however, tend to become fixed in the soil and are not liable to leach out. For this reason, N requirements usually govern the organic nutrient considerations in septage application rates.

Heavy Metals--

The phytotoxic metals zinc (Zn), nickel (Ni), and copper (Cu) are foliage-limiting factors in the amount of sludge which may be applied to the land. Cadmium (Cd) is also of concern due to its mobility in the plant structure and its toxicity to humans. How these metals are retained in the soil is complex and poorly understood, but workable estimates of application limits based on soil cation exchange capacity (CEC) have been proposed (24).

The CEC can be estimated by a displacement procedure which yields an exchange capacity in milli-equivalents (meq) per 100 grams of soil. A lifetime application load to any soil has been proposed by the Wisconsin Department of Natural Resources, limiting the amount of phytotoxic metal applied in terms of Zn equivalents. Further research into lifetime metal loading limits is underway, as it has been observed that some heavy metals may become tied up in the soil structure over a period of time through a reversion effect linked with a solid-state diffusion into crystalline soil structures. Attenuation of the effects of overapplication of phytotoxic metals in sludges to the land may be attributed to this mechanism.

The Wisconsin metal-loading criterion limits the Zn equivalent to 10% of the CEC. Zinc equivalents are based on Cu being considered twice as toxic as Zn, and Ni 4 times as toxic as Zn, although other researches have proposed relative toxicities in ratios other than 1:2:4.

The calculation of permitted lifetime loading of metal from septage, using the Wisconsin criteria, may be expressed as:

$$ML = (72.3(CEC)/(Zn) + 2(Cu) + 4(Ni))/1{,}000$$

where:

ML = maximum septage loading to soil, m^3 septage/acre
CEC = cation exchange capacity of soil, meq/100 g
Zn = Zinc content of septage, mg/l
Cu = Copper content of septage, mg/l
Ni = Nickel content of septage, mg/l

Cadmium toxicity presents a special problem in its mobility and its potential accumulation in the edible portions of plants. One recommendation for Cd limits is based on work in Wisconsin which found that application of greater than 2.24 kg Cd/ha/yr (2 lb Cd/acre/yr) showed a significant increase in metal concentration in plants. The proposed limits are 2.24 kg Cd/ha/yr (2 lb Cd/acre/yr), with a total lifetime loading of 22.4 kg Cd/ha (20 lb Cd/acre). (24) The proposed limits of phytotoxic metals and Cd are reported to be low enough to protect reasonably well chosen disposal sites.

Based on Lebanon, OH septage and Salotto findings (Table 6) approximately 8 times as much septage could be applied to the land as could municipal sludge using Cd as the limiting factor. Using the phytotoxic metals limit, approximately 5 times more septage could be applied as could municipal sludge. (14)

An example calculation for septage application rates, based on a combination of phytotoxic metals and Cd, again assuming average Lebanon, OH, septage and a soil CEC of 10 meq/100 g, is presented.

Metal Loading Calculation---

Septage Concentration:

Zn = 50 mg/l
Cu = 8.5 mg/l
Ni = 1.0 mg/l
Cd = 0.5 mg/l

1. Total Metal Equivalent Loading:
   72.3 x CEC = 723 kg/ha
   (650 lb/acre)

2. Septage metal equivalent per ton:
   (50 + 2(8.5) + 4(1.0))/1,000 = 71/1,000 = 0.071 kg metal equivalent per m^3 septage

3. Total lifetime loading permitted:
   (723 kg/ha)/0.071 kg/m^3 = 10,183.1 m^3/ha
   (6.65 mg/acre)

4. Yearly loading limit due to Cd:
   (2.24 x 1,000)/0.5 = 4,480 m^3/ha/yr (2.92 mg/acre/yr)
   for 2.24 kg Cd/ha/yr

The above calculations show that in this example, this site can receive a maximum of 10,183 m^3 septage/ha (6.65 mg/acre), (the phytotoxic limit), with a maximum yearly loading of 4,480 m^3/ha/yr (2.92 mg/acre/yr), (the Cd limit). Actual loadings should take into consideration the projected period of land use, potential septage generation rates, capability for spreading the material on the land, and the organic nutrient limitations as they relate to heavy metals limits.

It is interesting to note that the yearly loading based on Cd of 4480 m^3/ha/yr (2.92 mg/acre/yr) is 33.1 times the application rate based on the limiting N loading in this example of 560 kg/ha/yr (500 lb/acre/yr), assuming a TKN of 680 mg/l. Therefore, a well-drained site receiving this septage would have its phytotoxic metal loading lifetime of 75 years at the N application rate.

Pathogens--

The natural digestion process in a septic tank does not result in a pathogen-free material, as previously noted. For this reason, care must be always taken in handling this material.

Evidence for pathogen reduction when septage is exposed to atmospheric conditions is based on sewage sludge work performed by the MSDGC (25) and others. (26) As shown in Table 9, only 1%

of the original coliforms survived after 7 days. Table 10 shows basically the same reduction for sludge cake applied to the land. In a laboratory study on stored sludge, Berg determined the number of days of storage required to reduce several viruses and bacteria to 99.9% of the original values at different temperatures. (27) The results are shown in Table 11.

Pathogens reportedly have been removed in the soil by various mechanisms, predominantly filtration, adsorption, and die-off. Pathogen travel is usually restricted to several feet from point of application unless runoff or channeling occur, potentially polluting surface and groundwater.

While the Guidelines for Sludge Disposal on Agricultural Land in Wisconsin do not recommend raw sludge application without prior treatment, the partially digested septage may be applied if some preventive measures are followed, such as lagooning prior to land disposal, or the immediate application of lime to after spreading the septage. Care should be exercised in applying stored septage to the land, as cysts of protozoans and ova of helminths, frequently found in septage, are very persistent and constitute a health hazard. (22)

LAND DISPOSAL METHODS

Septage disposal techniques include surface application on the land by spreading from septage hauler trucks (Figure 6) or transfer vehicles such as tank wagons, spray irrigation, ridge and furrow practices, and overland flow. Subsurface application techniques include Plow Furrow Cover (PFC) and Subsurface Injection (SSI) alternates. Placement in trenches, lagoons, and Sanitary Landfills (SLF) are classified as burial practices.

Land Disposal-Surface Applications

This method of septage disposal is perhaps the most frequently used technique in the United States today. Future studies should give consideration to stabilization and additional pathogen reduction before surface application of septage on the land, as no discussion of septage health hazards in this respect is available.

With any surface application technique, some N loss occurs through ammonia volatilization, with the highest losses occurring from spray irrigation. (98)

TABLE 9. FECAL COLIFORM COUNTS OF STORED DIGESTER SUPERNATENT EXPOSED TO ATMOSPHERIC CONDITIONS (25)

Days	Fecal Coliform Counts (per 100 ml)	Percent Survival
0	800,000*	100.00
2	20,000**	2.50
7	8,000	1.00
14	6,000	0.75
21	2,000	0.25
35	20	0.01

* Fecal coliform count just prior to lagooning.
** Fecal coliform count after lagooning.

TABLE 10. DISAPPEARANCE OF FECAL COLIFORMS IN SLUDGE CAKE COVERING A SOIL SURFACE (26)

No. Days After Sludge Application	No. of Fecal Coliforms/gm Sludge Cake (Dry Weight)
1	3,680,000
2	655,000
3	590,000
5	45,000
7	30,000
12	700

TABLE 11. LABORATORY STUDY ON DAYS OF STORAGE REQUIRED FOR 99.9% REDUCTION OF VIRUSES AND BACTERIA IN SLUDGE (27)

	No. of Days at		
Organism	4°C	20°C	28°C
Poliovirus 1	110	23	17
Echovirus 7	130	41	28
Echovirus 12	60	32	20
Coxsackievirus A9	12	--	6
Aerobacter aerogenes	56	21	10
Escherichlia coli	48	20	12
Streptococcus faecalis	48	26	14

Land Spreading--

The hauler truck which pumps out the septic tank is frequently the vehicle which applies septage to the land. Consideration should be given to intermediate holding facilities before application to the land. Storage is necessary during or imminent to precipitation in order to prevent runoff of contaminated water. In colder climates, land application should be limited to non-frozen surfaces to prevent runoff during thaw conditions. Pathogen die-off with storage, presented under the previous heading, is also a factor indicating the necessity of storage.

With a storage facility, disposal can be performed either by the hauler truck or by a tank wagon usually pulled by a farm tractor. The choice between the two is one of economics. A larger operation may choose to have its trucks on the road, with septage spreading being performed by a separate spreading crew, thus freeing the more expensive tank truck to perform the cleanout functions. A smaller septage hauler may prefer to use 1 vehicle to perform both tasks, thus leveling the work load by spreading septage during slack hauling time periods. In some instances, soil conditions may require the use of floatation-type tires which are not suitable for long-distance highway use. This would dictate the use of separate collection and spreading vehicles.

Figure 6. Land spreading on farmland near Olympia, WA, showing area with recent discing of septage.

Spray Irrigation--

Spray irrigation of septage necessitates a storage lagoon prior to disposal. Portable pipes and nozzle guns are used rather than fixed or solid sets. Since the septage must be pumped at 80 to 100 psi through 3/4 to 2 in nozzle openings, installation of a screening device at the lagoon's pump suction is mandatory to prevent clogging at the distribution nozzles. Since spray irrigation also offers the greatest potential for offensive odors, knowledge of wind patterns and a well located site are important during the planning stage.

Ridge and Furrow--

Ridge and furrow disposal methods have been used to dispose of sludges on relatively level land, usually limited to slopes in the range of 0.5 to 1.5%. No instances of this practice were found during the course of this study. While this method can be used to distribute septage to row crops during their growth, care should be taken to ensure these crops are not for human consumption.

Overland Flow--

Overland flow disposal method is used as part of an overall septage-sewage and septage-sewage sludge treatment system at the Brookhaven National Laboratory in Upton, NY, and is described under the Meadow-Marsh-Pond system in this section. The overland flow field is planted with reed canary grass and has a slope of 3%. The operator suggests future designs should limit slopes to 1 1/2 to 2% to allow for cold weather operation. Several yearly harvests of grass crop can be made during growing season with multiple fields suggested. Current sizing criteria is 0.1 ha (0.2 acre) per 38 m^3/day (10,000 gpd) septage-sewage mixture.

Land Disposal-Subsurface Application

Soil incorporation techniques offer better odor and pest control than surface spreading techniques, plus likelihood of inadvertent pathogen contamination to humans is greatly reduced. Disadvantages include full incorporation of all N, since ammonia volatilization is eliminated, which reduces any N loading safety factor from ammonia loss in surface spreading. Costs increase over surface spreading, because a storage lagoon or tank becomes mandatory, and additional capital is required for the SSI equipment. A resting period of 1 to 2 weeks is required before equipment can be driven over the waste incorporated land.

Three methods have been used to inject septage into the land, including PFC, SSI, and a Terreator.

Plow-Furrow-Cover (PFC)--

A typical setup using this method consists of a single moldboard plow, a furrow wheel, and a coulter. The coulter blade is used to slit the ground ahead of the plow. Septage is applied to the land in a narrow furrow 15 to 20 cm deep and immediately covered with a following plow. Typical application rates were 0.012 m^3/m of travel (1 gal/ft), or on an area basis, 306 m^3/ha (32,700 gal/acre) in a Connecticut study. (97)

Subsurface Injection (SSI)--

This technique employs a device (Figures 7 and 8) which injects a wide band or several narrow bands of septage into a cavity 10 to 15 cm (6 to 8 in) below the surface. Some equipment uses a forced closure of the injection swath. Volumes injected may be varied from 0.6 to 3.8 m^3/min (150 to 1,000 gpm), depending on the number of sweeps or injectors on the unit. (28, 29) One study in Connecticut found no measured increase in groundwater pollutants. Acceptable loadings in this study were 0.025 m^3/linear m (2 gal/lin ft) for a volumetric loading of 407.5 m^3/ha (43,560 gal/acre).

Terreator--

This is a patented device (U.S. Patent No. 2,694,354) which opens a 9.5 cm (3.75 in), mole-type hole with an oscillating chisel point (Figure 9). An 11.4 cm (4.5 in) diameter curved tube then places the septage at 50.8 cm (20 in) below the surface at a rate of 24.8 l/lin. m (2 gal/lin ft). Passes are spaced 1.5 m (5 ft) apart for an application of 163 m^3/ha (17,400 gal/acre). Kolega found that subsurface application of 49 kg/ha of N (43 lb/acre) over 12 weeks in a well-drained soil did not produce any noticeable groundwater quality variation with either PFC, SSI, or Terreator methods. (30)

Land Disposal - Burial

Broad forms of septage burial include disposal in trenches, disposal lagoons and SLFs. Foul odors are endemic to these operations until a final soil cover is placed over the open surfaces of trenches or landfills. Disposal lagoon management practices, such as inlet design, location, or liming, try to minimize these problems.

Figure 7. Sludge disposal via SSI on a farmland near Boulder, CO.

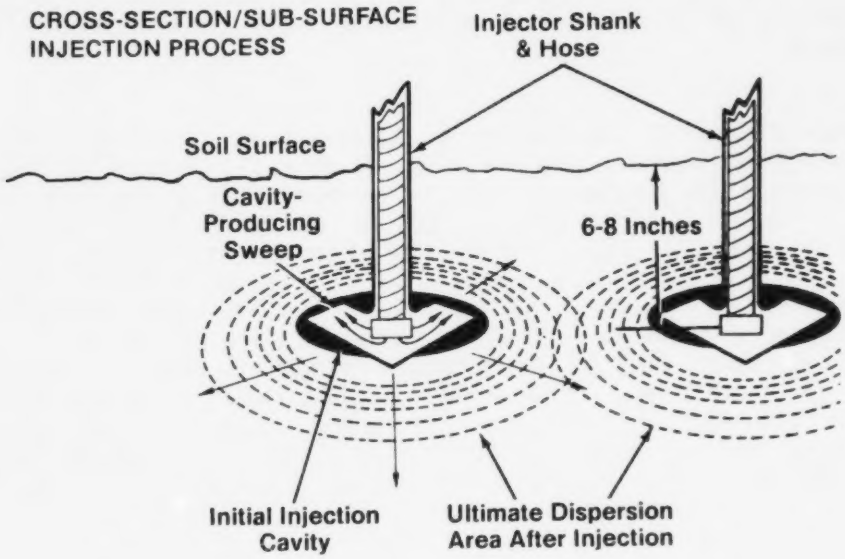

CROSS-SECTION/SUB-SURFACE INJECTION PROCESS
Injector Shank & Hose
Soil Surface
Cavity-Producing Sweep
6-8 Inches
Initial Injection Cavity
Ultimate Dispersion Area After Injection

Figure 8. Cross-section of SSI process.

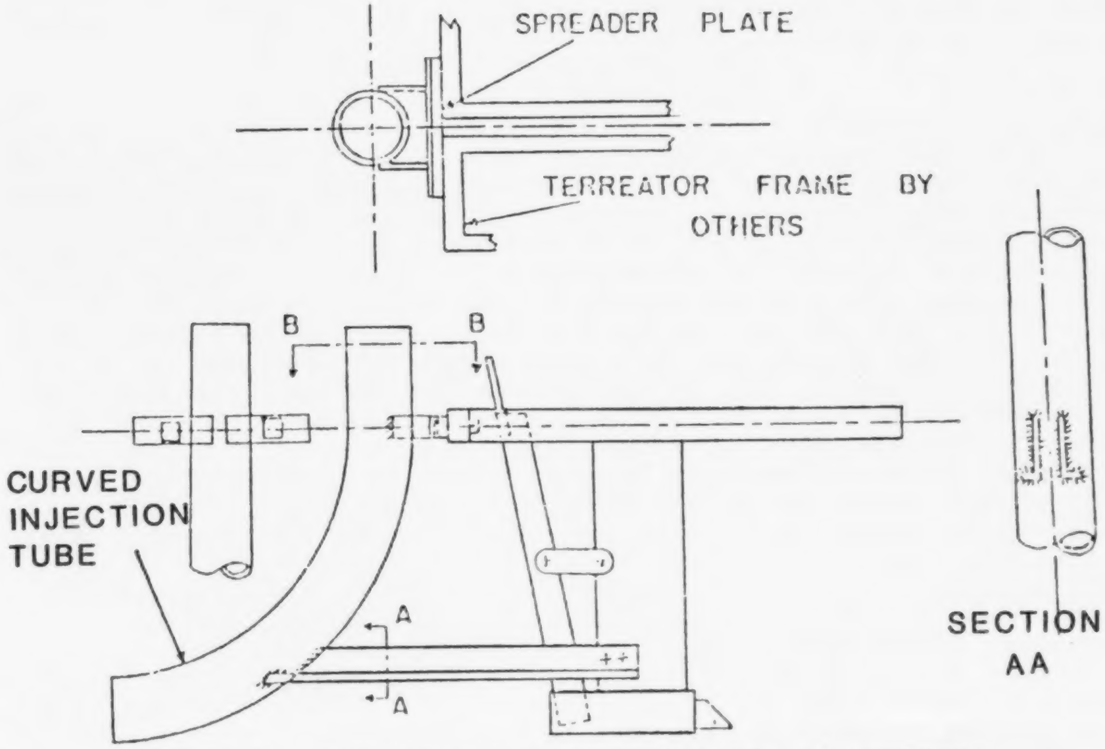

SPREADER PLATE
TERREATOR FRAME BY OTHERS
B
B
CURVED INJECTION TUBE
A
A
SECTION AA

Figure 9. Terreator apparatus for SSI of septage.

Site selection is important, not only for odor control, but also to minimize potential groundwater monitoring as an operational check.

Trenches--

Septage disposal in trenches is similiar to disposal in lagoons, except trenches are usually a smaller scale alternative to the lagoon. Septage is placed sequentially in one of many trenches in small lifts, 15 to 20 cm (6 to 8 in), to minimize drying time (Figure 10). When the trench is filled with septage, 0.6 m (2 ft) of soil should be placed as a final covering, and new trenches opened. An alternate management technique allows a filled trench to allow as much solids to settle as possible and as much liquid to evaporate and travel laterally and downward as possible. Then the solids are removed from the trench for disposal at a SLF. The trench can then be reused as long as some bottom and sidewall material is bucketed out with the septage to allow renewed leaching out of the clogged surfaces. If not, subsequent usage often requires greater time periods for liquid reduction as sides and bottoms of trenches may become further plugged, reducing liquid leaching rates.

New York recommends trenches be a maximum of 2.1 m (7 ft) deep. Sufficient room must be left between trenches for movement of heavy equipment. The trench and fill technique is quite often used at SLFs.

Disposal Lagoons--

Disposal lagoons (Figure 11) are usually a maximum of 1.8 m (6 ft) deep and allow no effluent or underdrain system. These disposal lagoons require placement of septage in small incremental lifts (0.15 to 0.30 m, or 6 to 12 in) and sequential loading of multiple lagoons for optimum drying. Series or series parallel lagoons with 2 years capacity each and a 0.6 m (2 ft) maximum depth are called for in New York State Guidelines. (31) After drying, solids may be bucketed out for disposal in a SLF in order to permit use of the lagoon for further applications. Alternatively, 0.6 m (2 ft) of soil may be placed over the solids as a final cover. Many states report odor problems with disposal lagoons, but may be controlled by placing the lagoon inlet pipe below the liquid level and having water available for haulers to immediately wash any spills into the lagoon inlet line.

Sanitary Landfills--

When a SLF (Figure 12) accepts septage, leachate production and treatment must be investigated. For moisture absorption, New Jersey recommends a starting value of 0.05 m^3 of septage to each m^3 of solid wastes (10 gal of septage to each yd^3).

Figure 10. Septage disposal trenches near Olympia, WA.

Septage should be prevented from entering landfills in areas with over 89 cm (35 in)/yr rainfall, those without leachate prevention and control facilities, or those not having isolated hydrogeological underlying rock strata.

A 15 cm (6 in) earth cover should be applied daily to each area that was dosed with septage, with a 0.6 m (2 ft) final cover within a week after the placement of the final lift. (10) Many designers suggest a maximum cell height of 2.5 m (8 ft). At this rate, 3.79 m^3 (1,000 gal) of septage could be distributed on 31.6 m^2 (340 ft^2).

Other Land Based Systems

Leaching Lagoons--

The State of Conneticut has been advocating leaching lagoon systems consisting of earthen anaerobic-aerobic sludge digestion cells. Septage is discharged into a vertical manhole at the edge of a lagoon and enters the lagoon at a point about 1/3 the distance from the front to the rear of the cell near the bottom. The lagoon bottom is not sealed, and at least 1/3 of the lagoon is above ground level to facilitate liquid removal by percolation and evapotranspiration. The minimum depth of the lagoon is

0.9 to 1.5 m (3 to 5 ft). Sludge is periodically removed, and the effluent from this anaerobic lagoon flows through a controlled outlet to an aerobic leaching lagoon. Lime addition is suggested to maintain pH between 6.8 and 7.2. However, it has been observed when lime is introduced into the influent manhole with the septage, the lime settles at the end of the anaerobic leaching lagoon influent pipe and exerts little or no effect on lagoon pH (Frederick Schauffler, NEIWPCC). Parallel sets of these series lagoons are recommended. The capacity of each cell is equal to 10% of the yearly septage influent volume, based on 0.2 to 0.26 m^3 (50 to 70 gal) of septage generated per capita of contributing population per year.

Massachusetts requires a minimum 1.8 m (6 ft) deep anaerobic lagoon, followed by at least 6 percolation beds having 0.04 m^2/m^3 (1 ft^2/gal) per day of design capacity. The lagoon design requirements call for a sizing of 3.79×10^{-3} m^3 (1 gal)/cap/day, with a minimum of 20 days retention at average flow. The recommended discharge pipe located below the liquid level has caused some problems by stirring up bottom sediments and releasing foul odors. Acton, MA (Figure 11) now allows haulers to discharge over rip-rap into the lagoon, which, they report, lessens odor problems. (10)

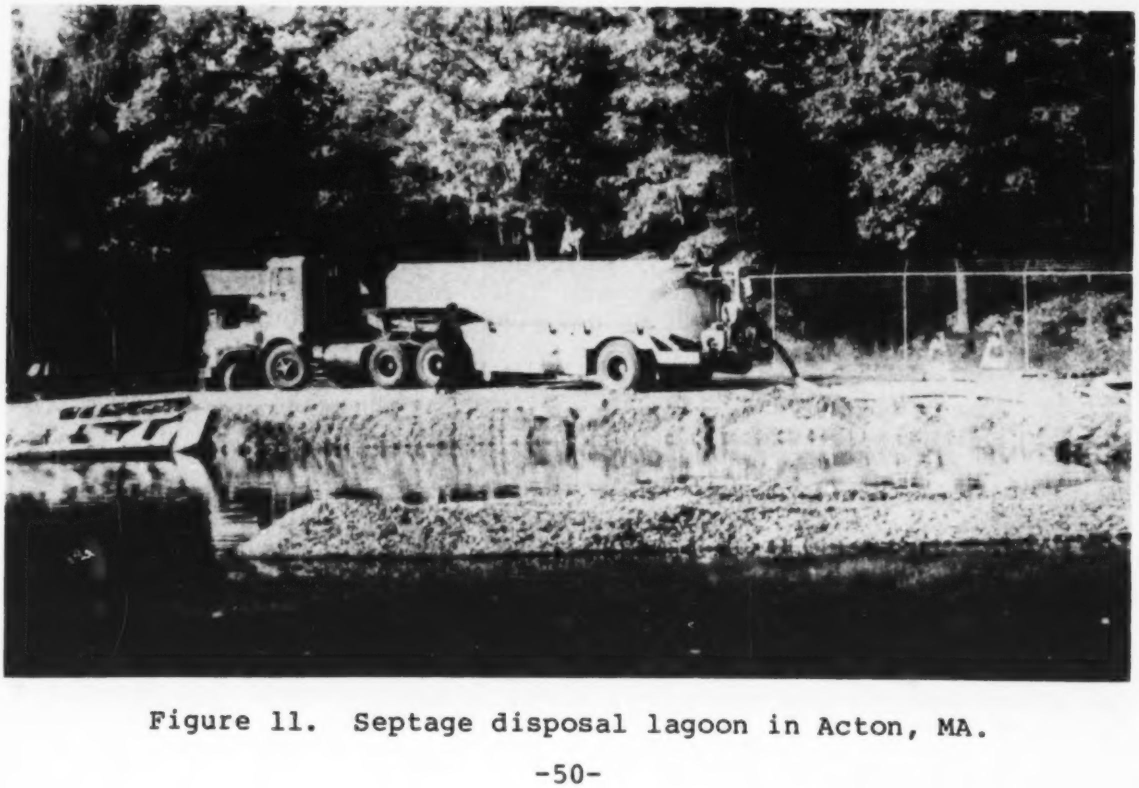


Figure 11. Septage disposal lagoon in Acton, MA.

Figure 12. Septage disposal in a SLF near Waretown, NJ.

Marsh-Pond System--

A land-based treatment system has been operating since April, 1975 at the Brookhaven National Laboratory in Upton, NY (Figure 13). This system treats strong blends of pretreated (aerated and comminuted) septage and sewage into a shallow marsh, then into a 5 foot deep stabilization pond. The marsh is sized for 468 m^3/ha/day (50,000 gal/acre/day), has a 20 mil PVC barrier over which 10 to 15 cm (4 to 6 in) of muck was placed prior to planting cattails. The 946 m^3 (250,000 gal) pond also has a 20 mil PVC barrier and has been stocked with carp, golden shiners, and fresh water clams. Duckweed (Lemna minor) is a free floating plant often associated with cattails, grows profusely, and keeps a high level of dissolved oxygen in the pond. Discharge from the pond is spread over a mixed pine and deciduous forest floor litter for infiltration to the ground water.

Various septage-sewage mixtures have been tried: 1:2, 1:10, and 1:5. At a 1:5 septage-sewage ratio, a composite average BOD_5 of 210 mg/l was achieved. The pond produces an effluent not over 30 mg/l BOD_5. Recently, higher strength loadings have been added to the system, consisting of a mixture of septage and settled sewage solids. Table 12 shows a typical influent and effluent concentrations from this marsh-pond system. (32)

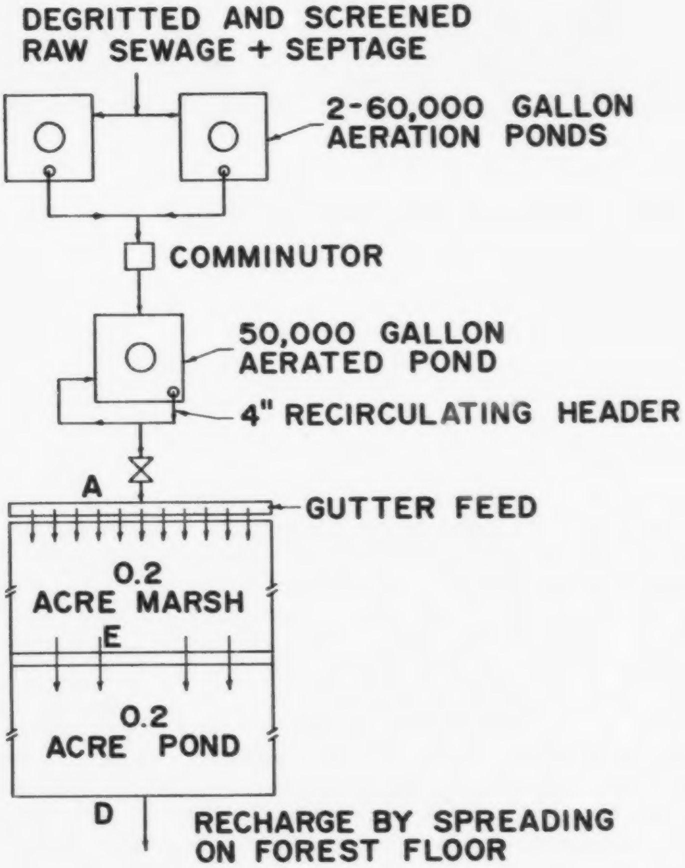

DEGRITTED AND SCREENED RAW SEWAGE + SEPTAGE
2-60,000 GALLON AERATION PONDS
COMMINUTOR
50,000 GALLON AERATED POND
4" RECIRCULATING HEADER
A
GUTTER FEED
0.2 ACRE MARSH
E
0.2 ACRE POND
D
RECHARGE BY SPREADING ON FOREST FLOOR

Figure 13. Schematic of marsh-pond system, Brookhaven National Laboratory.

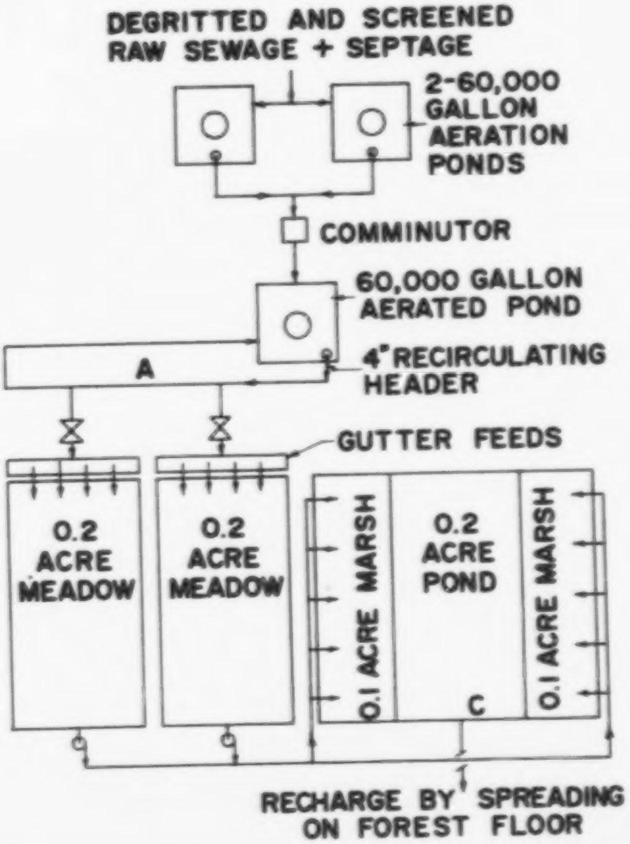
TABLE 12. CHARACTERISTICS OF MARSH-POND SYSTEM - AVERAGES FOR 13 MONTH STUDY PERIOD 8/75 - 8/76
(in ppm = mg/l except for pH and as noted)

	Pond Influent Concentration				Pond Effluent Concentration		
Parameter	Average	Maximum	Minimum	Effluent	Average	Maximum	Minimum
TS	5.62×10^2	5.3×10^3	2.0×10^2		2.06×10^2	3.0×10^2	1.42×10^2
TVS	3.35×10^2	3.64×10^3	83		1.02×10^2	1.42×10^2	40
TSS	3.53×10^2	4.3×10^3	50	30	43	1.0×10^2	14
TVSS	2.35×10^2	3.05×10^3	35		35	76	11
TDS	2.08×10^2	1.0×10^3	1.27×10^2	5.0×10^2	1.63×10^2	2.42×10^2	1.12×10^2
BOD_5	1.70×10^2	2.7×10^3	11	30	19	46	1
COD	4.95×10^2	7.9×10^3	33		58	1.2×10^2	20
Tot. N	25	91	12	10	9.5	18	2.5
TKN	19.7	88	5		6.8	14	1.7
NH_3-N	8.4	18	0.5		3.5	11.5	0.05
$NO_2 + NO_3$	5.5	17	0.7	10	2.6	6.7	0.4
Tot. P	7.2	27.7	2.5		2.1	4	0.4
PO_4	4.8	22	2		1.3	3	0.2
Tot. coli	*5.96×10^4	2.0×10^7	1.3×10^3	4	*2.0×10^3	2.34×10^5	40
F. coli	*1.56×10^3	1.0×10^5	0	2.0×10^2	*50	1.06×10^4	0
pH	6.8	8.9	4.8		7.4	9.1	6.2
Turb. (JTU)	43	4.0×10^2	0.3	5	8.5	74	0.7
Temp. (°C)	10	22	-4		11	24	-6
Spec. cond. (mho)	4.64×10^2	6.6×10^3	2.5×10^2		2.62×10^2	3.4×10^2	1.51×10^2
MBAS (ABS)	0.3	3	0.02	0.5	0.24	1.4	0.02
Ca	20	72	12	Sat.	14	26	8.8
Cl	35	1.1×10^2	25	2.5×10^2	30	46	15
Cr	0.05	0.5	0.01	0.05	0.01	0.03	0.01
Cu	0.7	3.2	0.2	1	0.03	0.14	0.01
F	0.5	1	0.2	0.6	0.4	0.6	0.2
Fe	3.6	20	0.8	0.3	1.2	5.5	0.3
Mg	4.3	8.5	3.4		3.6	6.3	2.1
Mn	0.14	0.75	0.06	0.05	0.1	0.3	0.4
K	5	11	2		4	9	0.5
Na	26	52	18	20	25	52	15
Zn	1.3	4	0.3	5	0.2	0.6	0.03

* Geometric mean #/100 ml

Meadow-Marsh-Pond System--

The meadow-marsh-pond system at the Brookhaven National Laboratory in Upton, NY, (Figure 14) is similiar in concept to the marsh-pond system described earlier except for the 0.16 ha (0.4 acre) meadow planted with reed canary grass. The meadows were excavated, a 20 mil PVC barrier was installed and the site was backfilled with silty loam. Three crops are harvested each year from the meadow area. The meadow has a slope of 3%, however, future installations should be limited to 2% to allow for more favorable wintertime operation. The pond in this system is stocked with catfish, fathead minnows and fresh water clams. A desirable hydraulic limit to this system has been established at 935 m^3/ha/day (100,000 gal/acre/day). (33) Pond effluent flows into a small ditch which flows through a forested area of mixed pine and deciduous trees before soaking into the sandy soil. Characteristics of influent and effluents are shown in Table 13.



DEGRITTED AND SCREENED RAW SEWAGE + SEPTAGE
2-60,000 GALLON AERATION PONDS
COMMINUTOR
60,000 GALLON AERATED POND
4" RECIRCULATING HEADER
A
GUTTER FEEDS
0.2 ACRE MEADOW
0.2 ACRE MEADOW
0.1 ACRE MARSH
0.2 ACRE POND
0.1 ACRE MARSH
C
RECHARGE BY SPREADING ON FOREST FLOOR

Figure 14. Schematic of meadow-marsh-pond system, Brookhaven National Laboratory. (33)

TABLE 13. CHARACTERISTICS OF MEADOW-MARSH-POND SYSTEM - AVERAGES FOR 13 MONTH STUDY PERIOD 8/75 - 8/76
(all in mg/l except pH and as noted)

Parameter	Average	Maximum	Minimum	Water Quality Criteria	Average	Maximum	Minimum
TS	5.62×10^2	5.30×10^3	2.0×10^2		1.80×10^2	3.65×10^2	89
TVS	3.35×10^2	3.64×10^3	83		87	2.41×10^2	6
TSS	3.53×10^2	4.30×10^3	50	30	39	1.04×10^2	13
TVSS	2.35×10^2	3.05×10^3	35		28	70	7
TDS	2.08×10^2	1.00×10^3	1.27×10^2	5.0×10^2	1.40×10^2	3.08×10^2	69
BOD_5	1.70×10^2	2.70×10^3	11	30	13	62	2
COD	4.95×10^2	7.90×10^3	33		48	1.20×10^2	16
Tot. N	25.2	91.1	12.5	10	5.2	15.6	1.3
TKN	8.4	18	0.51		1.2	6.8	0.04
NH_3-N	19.7	87.7	5		3.7	12.6	0.7
$NO_2 + NO_3$	5.5	17.3	0.68	10	1.5	3.2	0.2
Tot. P	7.2	27.7	2.5		1.6	5.3	0.3
PO_4	4.8	22.4	1.6		1.1	4.6	0.1
Tot. coli	5.9606×10^4	2.00×10^7	12.5	4	$*2.25 \times 10^3$	1.27×10^5	40
F. coli	1.557×10^3	1.00×10^6	20.0	2.0×10^2	*30	4.50×10^4	0
pH	6.8	8.9	4.8		6.9	9.2	6.1
Turb. (JTU)	42.7	4.00×10^2	0.26	0.5	4.8	71	0.6
Temp. (°C)	10.33	22	-4		10.6	24	-2
Spec. cond.	4.64×10^2	6.60×10^3	2.50×10^2		2.24×10^2	3.15×10^2	1.65×10^2
MBAS (ABS)	0.3	3.1	0.02	0.5	0.3	2.9	0.2
Ca	20	72	12	Sat.	14	47	9
Cl	35	1.10×10^2	25	2.50×10^2	29	85	17
Cr	0.5	0.5	0.01	0.5	0.02	0.3	0.01
Cu	0.7	3.2	0.2	1	0.04	0.2	0.01
F	0.5	1	0.2	0.6	0.3	0.5	0.2
Fe	3.6	20.1	0.8	0.3	1.5	3.9	0.3
Mg	4.3	8.5	3.4		3.3	4.4	2.3
Mn	4.9	11	2	0.05	0.1	0.5	0.03
K	26.4	52	18.2		3.1	11	8.9
Na	1.3	4	0.3	20	22.8	30	15.7

* Geometric mean.

Comparative Land Disposal Practices

The land disposal methods previously discussed in this section are compared in Table 14. This matrix assumes a moderately well-drained soil, N loading limitations, and northern climatic conditions (requiring use of holding tanks or lagoons in inclement weather). In surface spreading techniques, particularly spray irrigation, significant amounts of NH_3-N (25 to 50%) may be lost. (34, 35, 26) Although the amount of NH_3-N that may be lost is highly pH dependent, Jackson (98) has shown significant ammonia losses through spray irrigation occur: (1) by NH_3-N volatilization while the liquid is traveling from the sprinkler head through the air to the ground, and (2) by NH_3-N volatilization from the soil surface and from plant foliage during and shortly after spraying. The amount of NH_3-N that is lost directly affects the amount of sludge which may be added - i.e., the greater the loss, the higher the application rate.

SEPARATE SEPTAGE TREATMENT FACILITIES

Alternatives for treating septage at a separate treatment facility include aerated lagoons, anaerobic/aerobic processing, composting, high dosage chlorine oxidation (Purifax), and chemical treatment.

Aerated Lagoon

Aerated lagoons may be employed for treating septage if the aerators have the required oxygen transfer capacity and impart sufficient turbulance to prevent solids deposition.

Howley, in a laboratory-scale study (36), reported severe foaming problems with aeration. Measures were taken to control foaming, including placing a chemical mixer's blade several inches above the liquid surface to interfere with foam overflow. Foam fractionation was used successfully and had the added benefit of producing VSS and COD_5 removals of 31.0% and 50.2%, respectively of the initial concentrations. Two commercial silicone defoamers and anti-foamers (Dow Corning DB-110 and DB-31) were used at an application dose of 17 ml/l. Foaming in some samples with defoamer added reappeared after 24 hours.

When owners of septic tanks were questioned about use of detergents, there was almost a direct correlation between the presence of foam upon aeration and the use of detergents in a household. (36)

TABLE 14. LAND DISPOSAL CHARACTERISTICS

Land Disposal Method	Land Required at $37.9\ m^3$/day (10,000 gpd) Hectares (acres)	Characteristics	Advantages	Disadvantages
Surface Application				
Spray irrigation	150 (28.3) + storage + buffer zone	Large orifices for nozzle Irrigation lines to be drained after irrigation season	Use on steep or rough land	High power requirements Odor problems Possible pathogen dispersal Storage lagoon for pathogen destruction and during periods of wet or frozen ground
Ridge and furrow	162 (32.4) + storage	Land preparation needed	Low power requirements than spray irrigation Use in furrows on growing crops not for human consumption	Limited to 0.5 to 1.5% slopes Storage lagoon Some odor
Hauler truck spreading	162 (28.3) + storage	Larger volume trucks require flotation tires 500 to 2000 gal trucks Land requires rest between applications	Same truck can be used for transport and disposal	Some odor immediately after spreading Storage lagoon Slopes limited to 8%
Farm tractor with tank wagon spreading	162 (28.3) + storage	800 to 3000 gal capacity Requires additional equipment Land requires rest between applications	Frees hauler truck during high usage periods	Some odor immediately after dispersal Storage lagoon Slopes limited to 8%
Tank truck with plow and furrow cover	170 (32.4)	Single furrow plow mounted on truck	Minimal odor	Slopes limited to 8% Longer time needed for disposal operation
Farm tractor with plow and furrow	170 (32.4)	Septage discharge into furrow ahead of single plow Septage spread in narrow swath and immediately covered with plow	Minimal odor	Slopes limited to 8% Longer time needed than surface disposal Not usable on wet or frozen ground

(continued)

TABLE 14. (continued)

Land Disposal Method	Land required at 37.9 m^3/day (10,000 gpd) 250 days/year Hectares (acres)	Characteristics	Advantages	Disadvantages
Sub-surface injection	170 (28.3)	Septage placed in opening created by tillage tool	Injector can mount on rear of some trucks Minimal odor	Slopes limited to 8% Longer time needed for dispersal Keep vehicles off area for 1 to 2 weeks after injection Not usable in wet, frozen or hard ground
Burial				
Trench	6 (15)	New trenches opened when old ones filled	Simplest operation No slope limits No climatological limits	Odor problems High ground water restriction Vector problem Long term land commitment after termination of operation
Disposal lagoon	12 (30)	Lagoon is filled and dried, then covered with soil, or sludge bucketed out to landfill from bottom of septage lagoon	No slope limits No climatological limits	Odor problems High groundwater restrictions Vector problem
Sanitary landfill	79 (195) of working surface	Septage mixed with solid waste at controlled rates Consider leachate and collection requirements	No topographic limits Simple operation	Odor problems Rodent and vector problems Limit areas less than 35 inches yearly Rainfall or leachate collection or isolate from groundwater
Leaching lagoons	12 (30)	Sludge bucketed out to landfill from bottom of lagoon Multiple lagoons required Settled water usually flows to percolation - infiltration beds	No slope limits No climatological limits	Odor problems High groundwater restrictions Vector problems
Marsh/pond system	0.24 (0.4)	Low energy and low maintenance type treatment system Greater acreage required for higher strength wastes	Winter operation if increase freeboard No chlorination of effluent recommended No odor Simple operation	Rainfall counts as hydraulic load
Meadow/marsh/pond system	0.48 (0.8)	Same as above	As above, but produces better quality effluent	As above, but requires additional maintenance from harvesting 3 grass crops annually

Howley (36) found bench-scale removals with 1 and 5 day aerated lagoons achieving 74 and 91% COD reductions. He found higher oxygen uptakes by septage than sewage in this study, 54 mg/l/hr vs considerably lower 5 to 10 mg/l/hr, with soluble COD average decay rate of 0.218 day^{-1}. (37)

Howley also studied treatment in batch lagoon systems. Jewell and McCarty (38) presented a first order model describing this batch system as:

$$\frac{d}{dt}\left(\text{Total biodegradable organic mass}\right) = -k\left(\text{Total biodegradable organic mass, organic mass decomposed}\right)$$

or, $$\frac{d}{dt}\left(M_o - fM_o\right) = -k\left(M - fM_o\right) \tag{1}$$

where M_o = initial mass of VS

f = refractory fraction (non-biodegradable) = M_y/M_o

where M_y = the mass remaining after a long period of aeration (i.e., 1 yr)

k = reaction rate constant, day^{-1}

M = total mass of VS at any time, t

Integration of this equation gives:

$$\ln\left((M - fM_o)/(M_o - fM_o)\right) = -kt \tag{2}$$

Decomposition rates may thus be determined graphically by rearranging the above equation in the following manner:

$$\ln(M - fM_o) = -kt + \ln(M_o - fM_o) \tag{3}$$

which is analogous to a straight line plot on coordinate paper.

Results of a typical batch aeration unit after 45 days aeration (Figure 15) by plotting the results of this unit according to equation 3. Initial COD (total) was 74,400 mg/l, while initial COD (soluble) was 2,400 mg/l, and initial VSS was 33,000 mg/l.

After treatment, total COD was 55,000 mg/l, soluble COD was 680 mg/l and BOD_5 was 4.2 mg/l. No initial BOD_5 analyses were performed. He reported that (in a hypothetical example) a septage addition of 18,500 gpd/million gallons of aerated lagoon design capacity, operating at 50% of the design sewage flow, should not cause an overload condition.

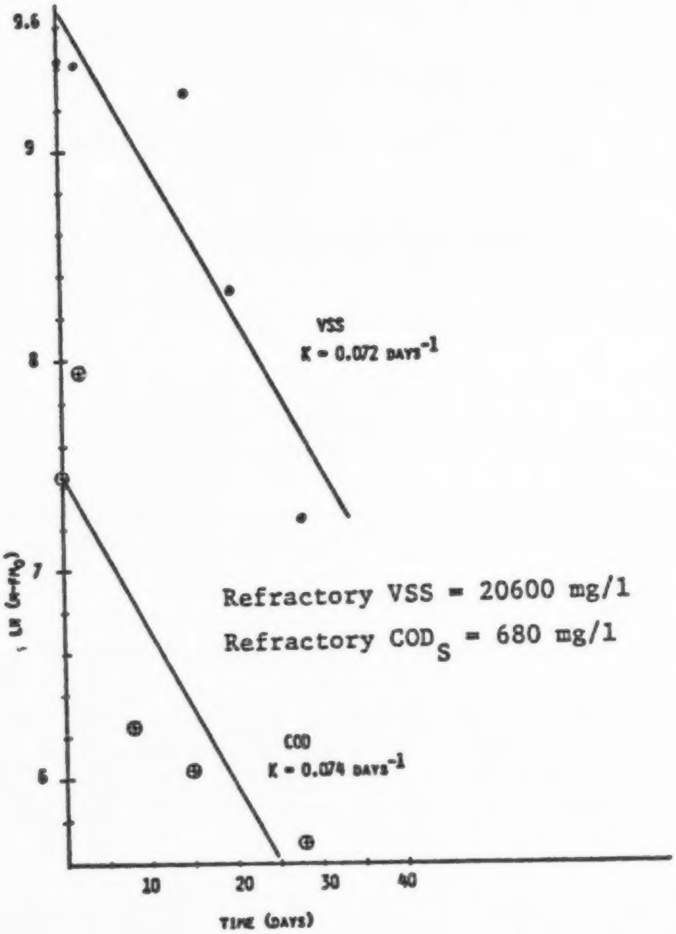


Figure 15. VSS and BOD_5 decay rate from a batch septage aeration unit.

Other studies using aerated lagoons to treat high strength industrial waste show effective treatment. In a pulp and paper mill (39), surface aerators treated a waste averaging 530 mg/l BOD_5, producing a reduction of 91% at a retention time of 3.6 days. The lagoon was loaded at 146 kg/m^3 (9.1 lb/1,000 ft^3). In a pilot plant study for an aerated lagoon system with sludge recycle treating vegetable processing wastes in Washington State (40) pea, corn, and carrot processing wastes showed between 95 to 99% reductions from influent BOD_5 levels which ranged from 1,503 to 3,550 mg/l. COD removals ranged from 92 to 98% from initial COD levels ranging from 2,155 mg/l to 5,450 mg/l. SS removals ranged from 83 to 97% from raw SS concentrations ranging from 428 mg/l to 1,350 mg/l. Detention time varied from 3 to 6 days.

In another study treating high strength vinegar waste in a batch two stage aerated lagoon with recycle (41), an influent BOD_5 of 5,500 mg/l was reduced to 194 mg/l in the settled effluent after 16 days. The COD was reduced from an initial 3,400 mg/l to 646 mg/l during the same time period.

The Town of Brookhaven, NY treats septage in an aerated lagoon system. (42) Figure 16 shows the original installation on top and revised present operating sequence on bottom. Table 15 shows performance of this system with sample No. 1 and 2 indicating normal performance of this system, and sample No. 3 indicating failure mode. The modified system has equalization facilities, but the plant suffers from poor operation (Personal Communications: John Esler, New York State Department of Environmental Control). Grit and scum chambers and three large settling lagoons (25 m x 25 m or 80 ft x 80 ft) now buffer flow to the 189 m^3/day (50,000 gpd) septage system. The effluent from a final settling lagoon is chlorinated and discharged to sand recharge beds. Accumulated sludge is removed to a nearby landfill.

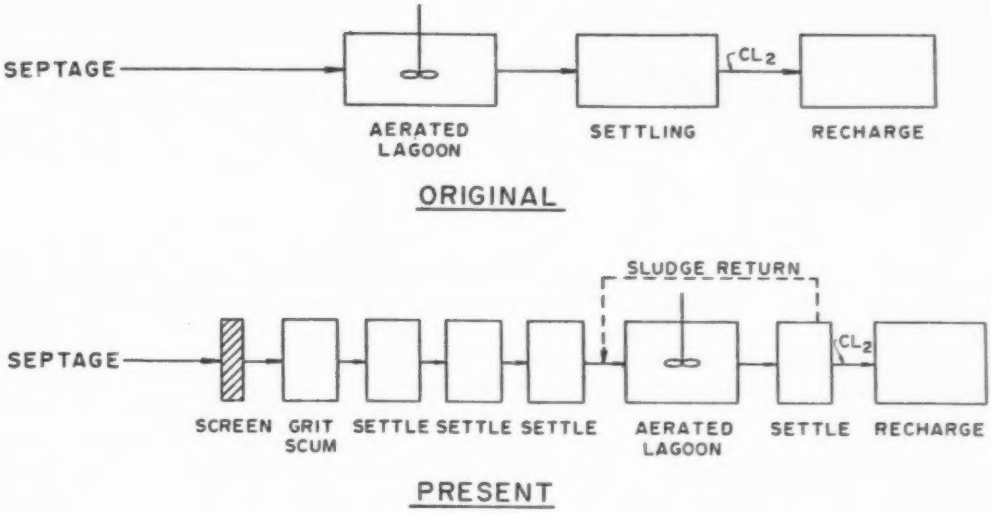

SEPTAGE
AERATED LAGOON
SETTLING
CL_2
RECHARGE
ORIGINAL
SLUDGE RETURN
SEPTAGE
SCREEN
GRIT SCUM
SETTLE
SETTLE
SETTLE
AERATED LAGOON
SETTLE
CL_2
RECHARGE
PRESENT

Figure 16. Septage treatment facility flow diagram for the town of Brookhaven, NY.

TABLE 15. ORIGINAL SYSTEM AERATION LAGOON PERFORMANCE AT BROOKHAVEN, NY (42)

Sample		Influent	Effluent Aeration Lagoon	Effluent Settling Lagoon	% Reduction (Total)
1	pH	6.0		6.15	
	BOD	7000		570	92.0
	COD	8200		840	90.0
	TS	10880		1061	90.5
	TVS	7800		574	92.5
	SS	7290		84	98.7
	VSS	5450		75	98.5
	% TVS	72.0		54	
	% VSS	74.8		89.2	
2	BOD			267	
	COD			1116	
	TS			1044	
	TVS			628	
	SS			270	
	VSS			250	
	% TVS			60	
	% VSS			92.8	
3	pH	9.4	7.2	6.8	
	BOD	5600	2100	3000	62.5
	COD	2749	2158	3328	+21
	TS	3686	1814	2382	50.8
	TVS	1964	1274	1740	35.1
	SS	2692	1364	1041	49.4
	VSS	1426	654	498	54.0
	% TVS	53.3	70.2	73.0	
	% VSS	53.0	47.8	47.9	

Anaerobic/Aerobic Process

The anaerobic/aerobic process, which uses an anaerobic lagoon or digester prior to an aerated lagoon, is generally used to reduce high strength wastes such as slaughterhouse or packing plant wastes. Bench scale and pilot septage treatability studies using anaerobic digestion followed by aerobic treatment and sand filtration were conducted at the University of Connecticut (97). High rate digestion was used for the anaerobic process, with 15 day retention in the bench scale study and 10 day retention for the pilot plant. Although temperatures were maintained between 32.2°C to 37.8°C (90°F to 100°F), the digester contents were not mixed. The aerobic process detention time is based on the removal requirements for BOD_5. A steady state material balance of BOD_5 is: BOD_5 influent (mg/day) - BOD_5 effluent mg/day) = BOD_5 removed mg/day), or

$$C_iQ - C_eQ = KV \qquad 4$$

where: C_i = Influent BOD_5 concentration, mg/l

C_e = Effluent BOD_5 concentration, mg/l

Q = Septage flow rate per day, liters/day

V = Aeration tank volume, liters

K = BOD_5 removal rate, (mg/l per day)

Since BOD_5 removal is considered to be a first order equation, the BOD_5 removal rate constant (K) is proportional to the effluent BOD_5 concentration. In a complete-mix unit,

$$\frac{dC}{dt} = K_eC \qquad 5$$

where: $\frac{dC}{dt}$ = the time rate of change in BOD concentration at any time, t

K_e = BOD_5 removal rate constant, day^{-1}

After equilibrium, the BOD_5 removal rate (K) is equal to K_eC_e. If we replace K with K_eC_e in (4) and $t = V/Q$, then:

$$(C_i - C_e)/C_e = K_et = K_et \qquad 6$$

$$C_e/C_i = 1/(1 + K_et) \qquad 7$$

where: C_e/C_i is the fraction of BOD_5 remaining

The percent BOD_5 removed is:

$$R = 100 - (100/(1 + K_et)) \qquad 8$$

The detention time t, in days, will then become:

$$t = R/((100 - R)K_e) \qquad 9$$

The researchers chose a K_e value of 0.5 for the anaerobic digester supernatant and a 95% BOD_5 removal through the aerated unit. The theoretical detention time is then calculated to be 38 days.

In the bench scale study (97) BOD_5 and COD concentrations of over 3,000 mg/l each were reduced by more than 96%. Sand filter effluents were 40 mg/l BOD_5 and 100 mg/l COD. The NH_3-N removal was 92%, and TKN removal was 94%. Overall VS reduction averaged 36%. Increases were noticed in NO_3-N concentration due to nitrification of NH_3-N in the aerobic treatment unit. Total phosphate removal was 92%, with the majority of phosphate removal occuring in the filtration unit. Chemical addition was not mentioned in this study.

The pilot plant anaerobic-aerobic septage treatment unit achieved similar removals to the bench scale unit. An initial BOD_5 concentration of 1,042 mg/l showed a 96% reduction after the aerobic treatment unit to an average effluent concentration of 35 mg/l. Sand filter effluent BOD_5 concentration averaged 4 mg/l. COD removal averaged 92% through the entire treatment scheme, including sand filtration. NH_3-N was reduced 99% and TKN showed a 96% reduction. An intermediate NH_3-N increase between the digester and the aeration unit was reported, from influent 59 mg/l to an effluent 80 mg/l. (97) (See Figure 17.)

NO_3-N effluent concentrations averaged 72 mg/l from the aerobic unit and 70 mg/l from the filtration unit. Total phosphate removal averaged 78% after the aerobic unit and 88% after sand filtration. VS removal in the pilot plant study averaged 29%, compared to 65% removal in the bench scale tests, possibly a result of considerable solids settling out in the pilot plant storage tank prior to introduction to the treatment unit. A 2.54 cm (1 in) rigid scum mat formed on the top of the digester, but did not interfere with its operation. (97)

Composting

Composting is an alternate septage disposal technique offering a potential for good bactericidal action and a 25% reduction in organic carbon. (43, 44)

Aerobic composting operations mix septage with dry organic matter for moisture control and for the addition of bulk to facilitate air penetration through the mixture to maintain aerobic conditions.

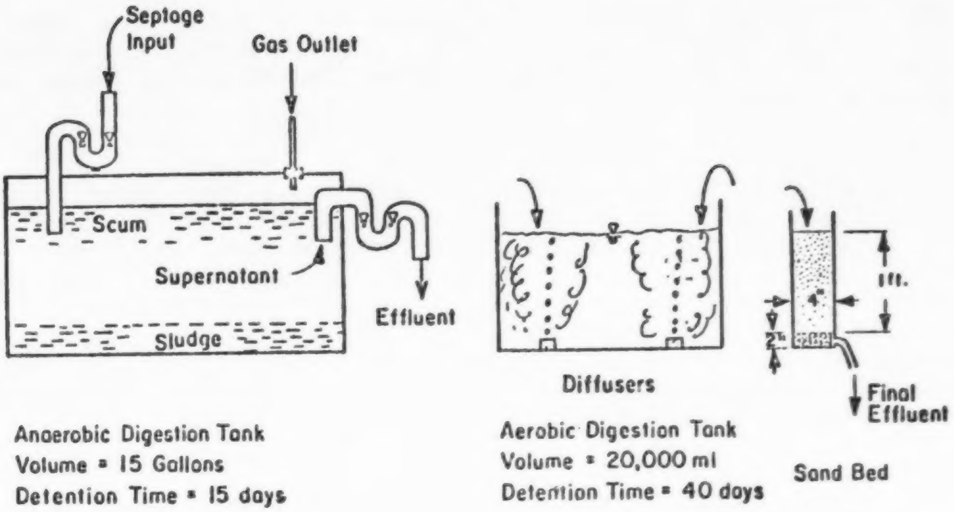

Septage Input
Gas Outlet
Scum
Supernatant
Effluent
Sludge
Anaerobic Digestion Tank
Volume = 15 Gallons
Detention Time = 15 days
Diffusers
Aerobic Digestion Tank
Volume = 20,000 ml
Detention Time = 40 days
1ft.
2"
Final Effluent
Sand Bed

Figure 17. Bench scale anaerobic-aerobic unit for septage treatment.

Aerobic composting is generally recognized as superior to anaerobic composting due to odor control, higher temperatures for pathogen control, and shorter periods necessary for stabilization. Two types of aerobic systems for composting septage currently exist, namely either the Lebo Process or the Beltsville Process.

Process Stages--

Three stages exist in composting. In the process initiation stage, temperatures pass from cryophilic (5°C to 10°C) to mesophilic (10° to 40°C) regions. Active composting can begin within days and operates in the thermophilic (40°C to 80°C) region. This temperature region tends to be self-limiting by competing mechanisms. With an abundance of substrate, bacterial populations increase, raising temperatures. Above 60°C, temperatures inhibit microbial growth, lowering population and temperatures until the operating point where optimum temperatures exist in balance with renewed growth. The third stage is substrate limiting, exhibiting continuously declining pile temperatures. This curing stage operates under two successive temperature regions, mesophilic (40°C to 10°C) and then cryophilic (10°C to 5°C).

Design

Composting areas should have ample room on-site for movement of heavy equipment, as well as tankage for septage equalization and for collection of leachate and surface water. Primary screening for removal of larger unwanted material is advised. After mixing with dry organic matter, compost piles are shaped into windrows or other shapes, such as cubes or hemispheres. Moisture control is achieved either by controlling the dry organic material/septage ratio (usually about 1.2 m^3 sawdust/-m^3 septage (6 y^3 sawdust/1000 gal)) or with increased aeration. Pile aeration can include either natural draft, mechanical mixing, forced (bottom) aeration, or by turning compost piles.

Lebo System--

The Lebo system shown in schematic (Figure 18) has been composting septage in South Tacoma, Bremerton, and Kent, WA. The Lebo method appears promising and uses a patented preaeration process prior to spraying septage on piles of sawdust, wood shaving, or other dry organic material. A 1 to 2 in application is covered with additional sawdust, until a 50 to 60% moisture content is achieved. The mixture is then formed with front-end loaders into piles to minimize heat loss. Natural draft aeration is possible because of the bulky nature of this mixture, eliminating the need for turning or forced aeration. Three months of composting the material at a thermophilic pile temperature between 40°C and 60°C greatly reduces numbers of fecal and total coliforms and eliminates salmonella bacteria. Pile temperatures may reach a maximum of 78°C. (43)

Beltsville System--

The Beltsville system, devised by U. S. D. A., is operating in Washington, DC; Bangor, ME; Durham, NH; Orange County, CA; and Johnson City, TN, on dewatered sludge. Camden, NJ will use the Beltsville forced aeration system (Figure 19) on 8% sewage sludge using licorice root as the bulking. The Beltsville system usually mixes dewatered sludge with wood chips in separate or extended piles and has piping facilities to alternately blow and pull air through 0.66 cm (0.25 in) holes in 15 cm (6 in) pipe covered by 30 cm (1 ft) of wood chips or screened compost to maintain aerobic bacterial action. (43, 44) After several weeks, the compost can be screened, recycling the residual wood chips for further composting. It may be necessary to dry the compost by spreading and periodically turning the material prior to screening. The composted material is then stockpiled prior to preparation and distribution.

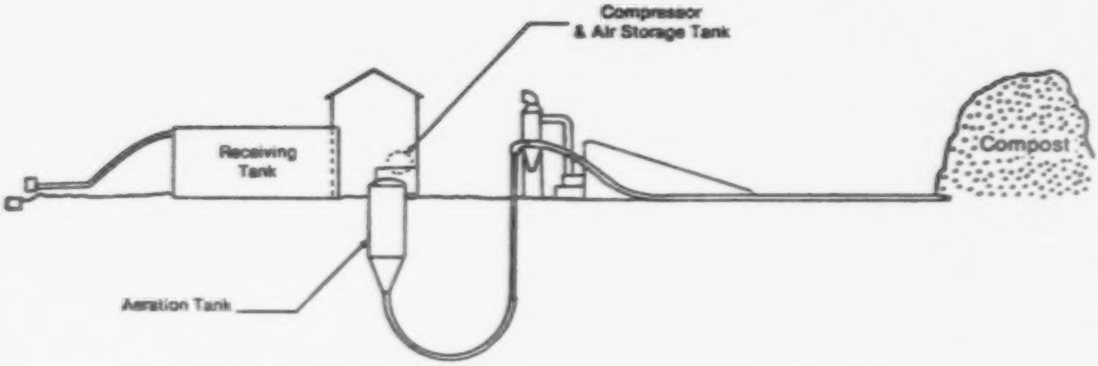

Compressor
& Air Storage Tank
Receiving Tank
Compost
Aeration Tank

Figure 18. Schematic of a typical Lebo composting facility.

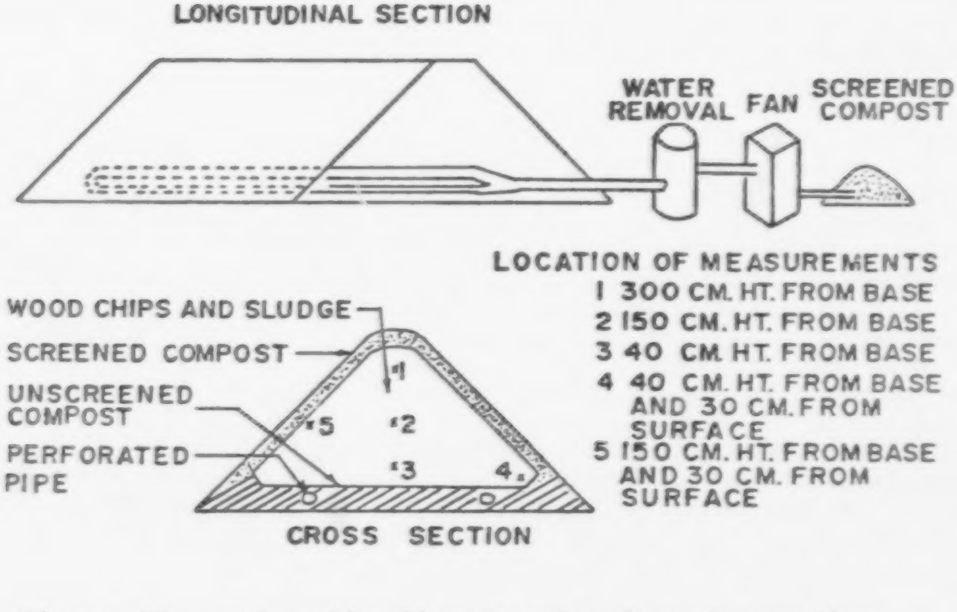

LONGITUDINAL SECTION
WATER REMOVAL
FAN
SCREENED COMPOST
LOCATION OF MEASUREMENTS
1 300 CM. HT. FROM BASE
2 150 CM. HT. FROM BASE
3 40 CM. HT. FROM BASE
4 40 CM. HT. FROM BASE AND 30 CM. FROM SURFACE
5 150 CM. HT. FROM BASE AND 30 CM. FROM SURFACE
WOOD CHIPS AND SLUDGE
SCREENED COMPOST
UNSCREENED COMPOST
PERFORATED PIPE
1
2
3
4
5
CROSS SECTION

Figure 19. Schematic diagram of a forced aeration compost pile system.

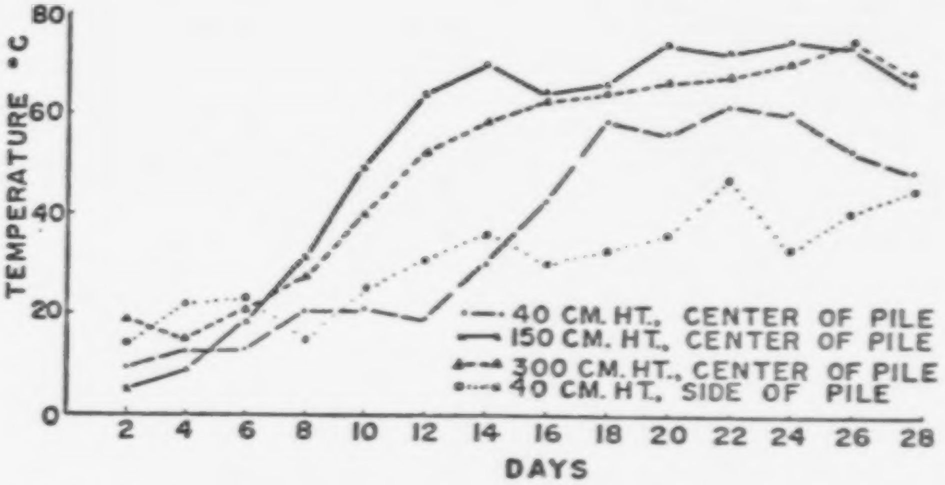


Figure 20. Temperatures in various locations within raw sludge compost pile shown in Figure 19.

End Use--

The end use of a compost depends on several factors to suitability as a fertilizer or soil enhancer, marketability, and cost.

Compost Quality-- Table 16 compares the composition of digested sludge, screened sewage sludge compost, and Lebo process compost from various aspects. Important considerations for use as a fertilizer are nitrogen-phosphorus-potassium (N-P-K) contents, the amount of heavy metals, and bacteriological quality. Compost tends to be low in N-P-K, and should be considered a soil ammendment rather than a fertilizer. Heavy metals from septage compost are significantly lower than those found in sludge products.

In a study on the effect of Lebo compost in conjunction with commercial fertilizer on sweet corn yield at Western Washington Research and Extension Center, (45) a residual effect of the compost caused a slightly increased yield during the second year of the test when no compost was applied. The application rate of 62,800 kg/ha (28 tons/acre) compost and 90 kg/ha (80 lb/acre) N provided a sweet corn yield of 18,800 kg/ha (8.4 tons/acre) in year one of this experiment. Although no fertilizer or compost was applied in the second year, a sweet corn yield of 19,700 kg/ha (8.8 tons/acre) was harvested, thus showing a 4.7% increase in yield.

TABLE 16. COMPARISON OF DIGESTED SLUDGE, SCREENED SEWAGE SLUDGE COMPOST, AND LEBO COMPOST CHARACTERISTICS

Component	Digested Sludge %	Screened Compost %	Lebo Compost %
Filter cake			
H_2O	80	35	59
TS	20	65	41
Sol. frac.			
Org. matter	50	50	75
N	2.5	0.9	.77 - 1.37
H_3PO_4	2.7	2.3	0.3
KOH	0.6	0.2	0.05 - 0.35
S	0.9	0.4	--
Ca	2.9	2.6	3
Mg	1	0.3	0.075
B**	23	27	80
Heavy metals			
Zn**	2.0×10^3	1.0×10^3	4.0×10^2
Cd**	19	9	10
Cu**	6.0×10^2	2.5×10^2	50
Pb**	5.4×10^2	3.2×10^2	60
Micro-org.			
Tot. coli***	2.4×10^{10}	9.7×10^4	$460 - 1.1 \times 10^5$
Fec. coli***	2.3×10^{10}	3.0×10^3	3 - 93***
Salmonellae***	6.0×10^3	0	--

* The composition of digested and composted sludge is subject to considerable variation. Values in the table are approximate averages. Variations in composition occur because of the different wastes discharged, chemical additions, types and degrees of treatment, and bulking materials used.

** Parts per million.

*** Most probable number per hundred grams of sample.

Bacteriological quality is good, especially from the standpoint of resistant pathogenic organisms, such as ova and cysts. If the entire compost product attains a temperature of 60°C (140°F) for 3 months or longer, these organisms do not prove to be a biological hazard. (22) Therefore, before a Lebo compost pile is to be marketed, the outer layer of the pile, to a depth of 1 foot, is skimmed off and used as seed for the next pile, since the outer layer is not exposed to the composting temperatures of the pile interior. (46)

Marketability-- In a recent survey of the marketability of sludge products, a strong market for such products was detailed. (47) The range of sludge product costs ran from zero to $.20/kg ($180/ton), with composted products ranging from no charge at Beltsville, MD (available only to municipalities) to $0.07/kg ($1.59/50 lb bag) for Los Angeles composted sludge, bagged and resold by the Kellog Supply Company. Demand for Beltsville compost exceeds supply, and the product is not promoted heavily. Lebo compost has had some success at distributing their product to golf courses in bulk with an approximate cost of $0.0022/kg ($2.00/ton).

Ettlich found successful marketing operations generally include: 1) favorable local publicity, 2) availibility of the product for pick up or delivery, 3) offering suggestions or guidelines for use, 4) keeping the price extremely low, and 5) giving the product a trade name. (47)

High-Dosage Chlorine Oxidation (Purifax Process)

The BIF-Purifax process oxidizes screened, degritted and equalized septage with dosages of Cl from 700 mg/l to 3000 mg/l under 308 kPa to 377 kPa (30 to 40 psig) pressure. Chlorine replaces oxygen in organic molecules, rendering this material unavailable to bacteria as a food source and in the same process stabilizing and deodorizing the septage. The purifaxed septage changes color from black or deep brown to straw color. The process initially releases CO_2 gas which separates liquids and solids quickly by imparting an effective flotation of the solids.

In domestic septage, the following compounds react significantly with Cl; ammonia, amino acids, proteins, carbonaceous material, nitrates, and hydrogen sulfide. The reaction time is pH dependent, being faster at lower pH. The reactions detailed in Feng's work, (48) verify the reduction of NH_3-N, BOD, COD, and TOC. Organic removal is generally increased with Cl_2 concentrations and time.

Purifax treatment results in a highly acidic slurry whose pH ranges from 1.65 to 2.02. (48) If mechanical dewatering or lagoon separation of the liquids or solids is contemplated, chemical addition for pH control of the resultant liquid fraction must be included. At Ventura, CA, 1.7 kg (3.7 lb) of caustic is added per 3.785 m^3 (1,000 gal) of decant to achieve a pH of 6.0. (7)

A Purifax treatment scheme, studied at Lebanon, OH, involved a pressure-chlorination of septage followed by dewatering on sand drying beds. Analyses of underdrainage showed LAS, COD, P and Fe removal of 99%, BOD_5 removal of 97%, Zn removal of 96% and N removal of 83%. (14)

Only 1 to 2 1/2 days were required to dry a 15 to 30 cm (6 to 12 in) application to 30% solids. The sand bed underdrainage was measured to be at a pH 6.8 to 7.2. (14)

Other locations treating septage or septage-municipal sludge mixtures by the Purifax process include: Plainfield, and Putnam, CT; Easthampton, MA; and Ventura, CA (Figure 21). Some sites utilizing lagoons for liquid-solid separation have had periodic solids separation and odor problems. Sand drying beds appear to be the most efficient method of liquid-solids separation. Adequate ventilation of covered sand drying beds is mandatory to eliminate operator health hazards from inhalation of any NCl_3 released subsequent to the Purifax process.

The EPA is currently analyzing pressure chlorinated sludge and septage for chlorinated organics formed by this process to determine the potential environmental impact of this form of processing.

Chemical Precipitation

Raw septage is chemically treated with lime and ferric chloride at Islip, Long Island and, until recently, at Oyster Bay, NY treatment facilities (Figure 22). After screening and degritting, the septage flows to a tank equipped with heavy duty paddle mixers, designed to prevent deposition of SS in the two day equalization tank. Operational difficulties were encountered in keeping the waste completely mixed. About 0.04 kg lime/kg dry solids (190 lb lime/ton dry solids) and 0.00021 m^3/kg dry solids (50 gal/ton dry solids) of a standard strength ferric chloride solution is flash-mixed with the septage. The solids-liquid separation step occurs in a clariflocculator. An observed significant solids carryover problem indicates the separation unit may have been undersized. The liquid fraction is chlorinated and discharged to ground water recharge beds. Polymer is added to the underflow solids from the clariflocculator which is then vacuum filtered, with the fil-

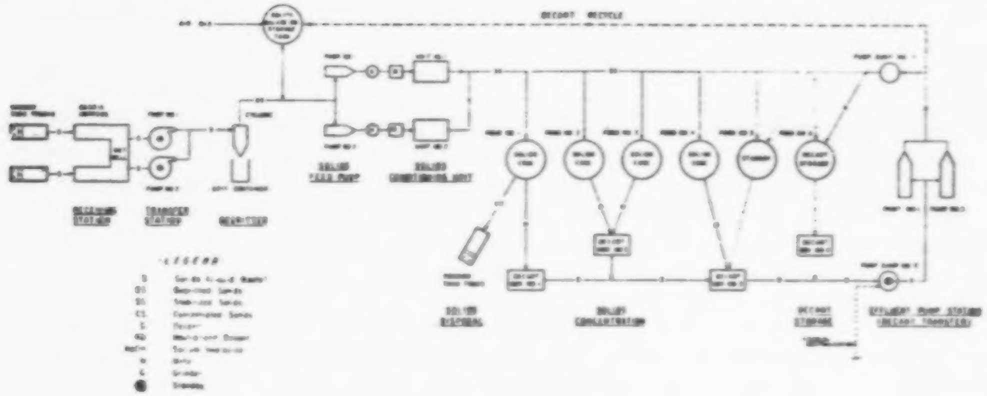

DECANT RECYCLE
SOLIDS FEED PUMP
SOLIDS CONDITIONING UNIT
LEGEND
SOLIDS DISPOSAL
SOLIDS CONCENTRATION
DECANT STORAGE
EFFLUENT PUMP STATION
(DECANT TRANSFER)

Figure 21. Details of Ventura, CA high dosage chlorine oxidation system for treating septage.

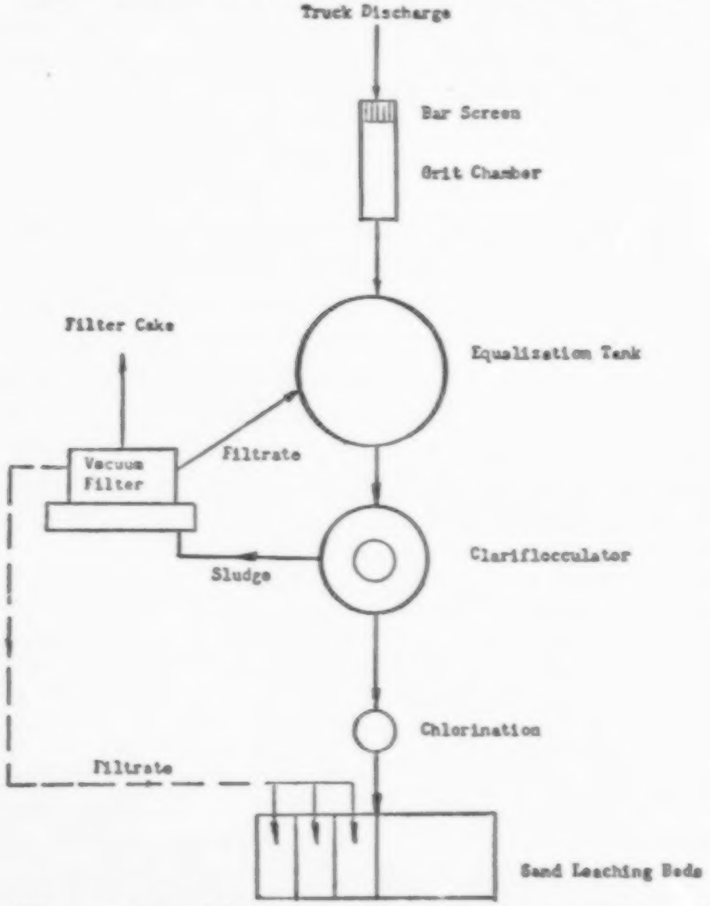

Truck Discharge
Bar Screen
Grit Chamber
Filter Cake
Equalization Tank
Vacuum Filter
Filtrate
Clariflocculator
Sludge
Chlorination
Filtrate
Sand Leaching Beds

Figure 22. Schematic of Islip and Oyster Bay chemical precipitation septage treatment facilities in NY.

trate being returned to the equalization tanks or flash mixers. (7, 49) Long term relative stability of the lime-ferric septage mixture is unknown.

Design parameters include clariflocculator sizing at 30 minutes detention time in the flocculation zone, and an overflow rate of 24.5 m^3/day/m^2 surface area in the settling zone (600 gpd/ft^2). Komline-Sanderson coil filters were based on laboratory findings of 24.4 kg sludge cake/m^2 of filter area, but in actual experience, the yield was only between 10 to 15 kg sludge cake/m^2 filter area (2 to 3 lb/ft^2 filter area). The later designed Islip plant has a 27.9 m^2 (300 ft^2) of filter area to account for field experience. Long Island soil conditions dictate at least 0.12 m^3 per day/m^2 (3 gpd/ft^2) of recharge bed. (49)

Operational experience of both the Oyster Bay and Islip plants are presented in Table 17, and include averaged test data from Nassau County Department of Health correspondences and other sources over a multi-year period. (9)

TABLE 17. PERFORMANCE DATA FROM CHEMICAL PRECIPITATION PLANTS IN ISLIP, AND OYSTER BAY, LONG ISLAND, NY

Plant Parameter		Influent	Clariflocculator Effluent	Vacuum Filter Effluent
pH	I*	6.8	11.8	11.8
	OB**	6.4	11.9	12.4
BOD	I	2,800	1,823	77
	OB	740	282	434
COD	I	8,060	9,212	223
	OB	----	----	----
SS	I	987	2,842	4,454
	OB	----	----	----
% VSS	I	----	----	----
	OB	----	85	58.1
TS	I	1,660	5,204	6,645
	OB	80,714	1,728	3,060
% VTS	I	----	----	----
	OB	47.3	35.8	31.6

* Islip, NY data. ** Oyster Bay, NY data.

Tilsworth found good liquid - solid separation only with huge additions of chemicals; for example, either 10,000 mg/l lime, 10,000 mg/l ferric sulfate, 4,000 mg/l lime and ferric sulfate mixture, or 30,000 mg/l of a cationic polymer. (52)

The NEIWPCC suggests (in unpublished test data) that primary settled septage can be reduced to 50% original volume in 1 to 2 hours and to 25% original volume after 2 to 4 hours after additions of 0.08 kg lime/kg dry solids plus variable amounts of both $FECl_3$ and an anionic polymer.

Rotating Biological Contactors

After various septage handling schemes were analyzed for the Wayland-Sudbury, MA area, a treatment system using rotating biological contactors (RBC) was proposed. (8, 50, 51) The scheme using RBC's was based on a design at Ridge, NY. The Ridge design treats an equalized and screened wastewater with a BOD_5 of 325 to 402 mg/l and SS of 130 to 145 mg/l in a 2,323 m^2 (25,000 ft^2) disc area RBC. (54) RBC effluent characteristics are BOD_5 of 32 to 48 mg/l and SS of 42 mg/l. The wastewater then flows from the RBC clarifier to 0.02 m^3/ min/m^2 (2 gpm/ft^2) sand filtration units for disposal in 0.06 m^3/ day/m^2 (5 gpd/ft^2) sand recharge beds. Sludge is thickened, then stabilized with chemical addition by ferric chloride and sodium hydroxide and vacuum filtered at the rate of 29.3 kg/hr/m^2 (6 lb/hr/ft^2). Effluent to sand recharge beds averaged 7 mg/l BOD_5 and 6 mg/l SS.

The two alternatives suggested for Wayland-Sudbury using RBC's are shown in Figures 23 and 24. Figure 23 shows Alternate II, the recommended alternate. (Alternate I is the Purifax Process) Figure 24, showing Alternate III, is a more costly treatment scheme replacing chemical equalization with anaerobic digestion. (8) Major unit sizing for this 95 m^3/day (25,000 gpd) facility is identical to the Ridge, NY plant, except that the size of the rapid sand filters was doubled for the Massachusetts design.

Wet Air Oxidation

The wet air oxidation process has been used in Japan to treat night soil wastes. (55, 56) Night soil is accumulated human wastes, stored outside homes, and pumped on a routine basis. The material has many of the same concentrations as septage, but it differs considerably from septage in that it is much less septic (days compared to years), so it is neither subjected to the same degree of decompositon, nor is it subjected to elutriation, as septage is. Typical parameter values for night soil include a high pH (8.1 to 9.0), TS of 29,300 to 35,000 mg/l, BOD_5 of 10,000 to 14,000 mg/l and an NH_3-N of 3,000 to 3,900 mg/l. (55) Therefore, this type of treatment may be applicable to septage stabilization.

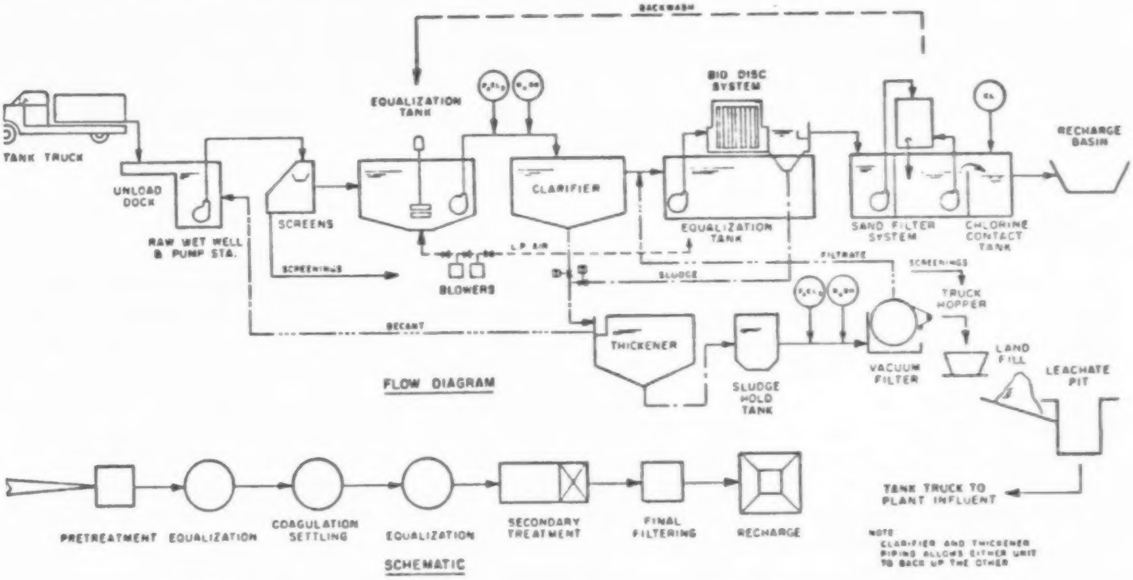

BACKWASH
TANK TRUCK
UNLOAD DOCK
RAW WET WELL & PUMP STA.
SCREENS
SCREENINGS
EQUALIZATION TANK
BLOWERS
L.P. AIR
CLARIFIER
DECANT
BIO DISC SYSTEM
EQUALIZATION TANK
SAND FILTER SYSTEM
CHLORINE CONTACT TANK
RECHARGE BASIN
FILTRATE
SLUDGE
SCREENINGS
TRUCK HOPPER
THICKENER
SLUDGE HOLD TANK
VACUUM FILTER
LAND FILL
LEACHATE PIT
TANK TRUCK TO PLANT INFLUENT
FLOW DIAGRAM
PRETREATMENT
EQUALIZATION
COAGULATION SETTLING
EQUALIZATION
SECONDARY TREATMENT
FINAL FILTERING
RECHARGE
SCHEMATIC
NOTE
CLARIFIER AND THICKENER PIPING ALLOWS EITHER UNIT TO BACK UP THE OTHER

Figure 23. Wayland-Subury, MA septage treatment alternative II - aerobic treatment.

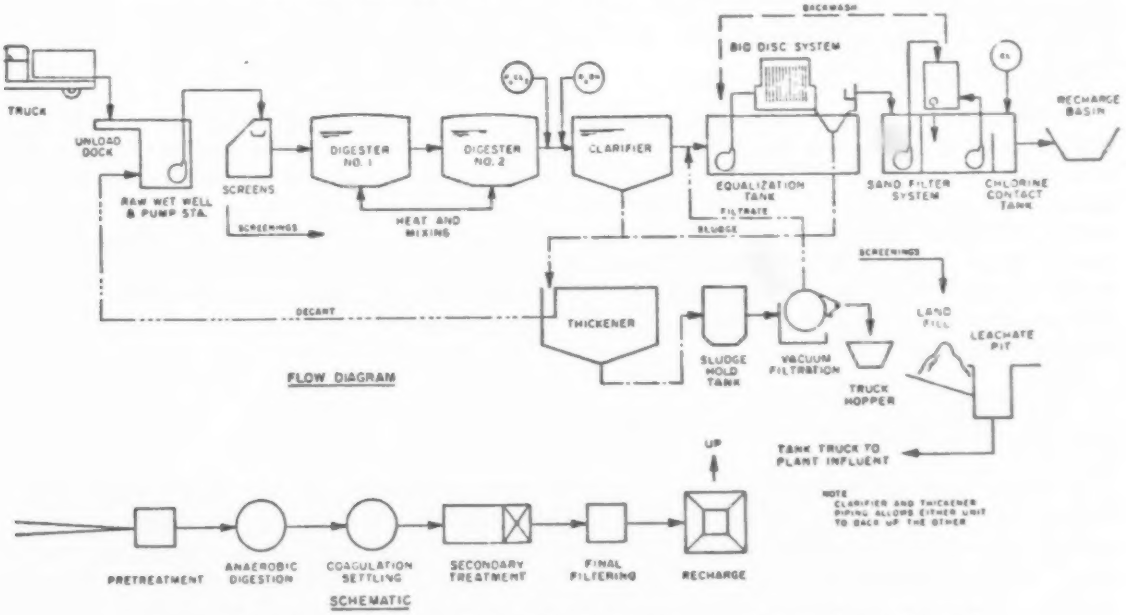

BACKWASH
BIO DISC SYSTEM
TRUCK
UNLOAD DOCK
RAW WET WELL & PUMP STA.
SCREENS
SCREENINGS
DIGESTER NO. 1
DIGESTER NO. 2
HEAT AND MIXING
CLARIFIER
EQUALIZATION TANK
SAND FILTER SYSTEM
CHLORINE CONTACT TANK
RECHARGE BASIN
FILTRATE
SLUDGE
SCREENINGS
DECANT
THICKENER
SLUDGE HOLD TANK
VACUUM FILTRATION
TRUCK HOPPER
LAND FILL
LEACHATE PIT
FLOW DIAGRAM
TANK TRUCK TO PLANT INFLUENT
UP
NOTE
CLARIFIER AND THICKENER PIPING ALLOWS EITHER UNIT TO BACK UP THE OTHER
PRETREATMENT
ANAEROBIC DIGESTION
COAGULATION SETTLING
SECONDARY TREATMENT
FINAL FILTERING
RECHARGE
SCHEMATIC

Figure 24. Wayland-Subdury, MA septage treatment alternative III - anaerobic/aerobic treatment.

Wet air oxidation studies at the Chubu STP, Yokohama, Japan, were performed on night soil mixed with air at pressures between 5.6×10^6 pa and 8.4×10^6 pa (800 to 1,200 psig) and heated to temperatures of 185° to 210°C (365° to 410°F) in heat exchange tubes. The mixed oxidized material showed a high pH, a 9 to 38.2% TS reduction, a BOD_5 reduction of 13 to 39.3%, but no change in NH_3-N and total N concentrations. The oxidized material characteristically exhibits excellent settling properties, with a supernatant pH of 7.8 to 8.5, VS of 8,000 to 17,400 mg/l, a BOD_5 of 6,500 to 9,500 mg/l and NH_3-N of 3,140 to 3,720 mg/l. The settled sludge also had a pH of 7.8 to 8.5, a BOD_5 of 8,800 to 15,600 mg/l and VS of 14,600 to 33,000 mg/l. The clarified liquid was then shown to be amenable to biological treatment. After diluting the oxidized waste to a maximum of 900 mg/l BOD_5, Ikeda found excellent BOD reductions can be expected with a BOD_5 loading of 80 kg BOD_5/100 kg MLSS/day and 1.5 kg/m^3/day loading limit on the aeration tank. The stabilized sludge solids have a significantly improved filtering ability, and can be dewatered on a filter press. The tendency of the wet air unit to accumulate scale on the exchange tubes can be counteracted by weekly flushing with 5% nitric acid at operating pressure and temperature. Treating night soil in a unit with heat exchangers of 304 stainless steel did result in corrosion, especially at pipe bends. After 1,000 hours of operation, all surfaces, except titanium materials, developed pitting, corroded holes, and cracking. With night soil, the current material of choice in a wet-air oxidation unit is titanium.

Autothermal Thermophilic Aerobic Digestion

An ATAD at Cornell University is currently treating domestic animal waste, and soon will test treatment of septage. The two stage reactor system is based on pilot plant work performed at Tonowanda, NY using pure oxygen, whereas the Cornell study is using an air supply. Using covered, well insulated tanks, and small gas flows of pure oxygen, reactor temperatures up to 65°C can be obtained by taking advantage of the exothermic reactions of aerobic digestion. The lower gas volumetric flow rate of a high purity oxygen supply (about 1% of an air flow system) carries away much less heat in the form of H_2O evaporation then does an air supply, allowing inherent thermal efficiencies to be realized in the oxygen system. (53)

The two stage system at Tonowanda resulted in an overall VS reduction of 29.1 to 41.9% at VS loadings from 12.8 to 16.0 kg VS/day/m^3 (0.032 to 0.46 lb VS/day/ft^3). (53) A two stage system was used, as it proved more temperature stable than a one stage reactor system. The first stage is temperature limiting (reaction rates decrease above 65 to 70°C), while the second stage is substrate limiting. Table 18 shows results of VS reductions at the Tonowanda pilot plant.

TABLE 18. VOLATILE SOLIDS REDUCTIONS AT TWO STAGE AUTOTHERMAL THERMOPHILIC AEROBIC DIGESTION (ATAD) PILOT PLANT AT TONOWANDA, NY (53)

Stage 1

Phase	Feed	Retention Time (days)	Temp. °C Max/Mean	VS Load kg VS/day/m^3 (lb VS/day/ft^3	% VS Reduction
I	WAS*	2.1	55.0/48.7	11.05 (0.69)	27.9
III	Unox WAS	1.7	57.8/50.1	15.86 (0.99)	22.1
III	Unox WAS and PS**	2.3	54.7/49.3	13.94 (0.57)	26.9

Stage 2

I	WAS	2.5	50.3/50.3	6.89 (0.43)	19.5
III	Unox WAS	2.0	57.8/57.3	10.59 (0.66)	12.5
III	Unox WAS and PS	2.7	54.8/54.8	9.13 (0.57)	12.5

Overall Reduction

Phase	Retention Time (days)	VS Load kg VS/day/m^3 (lb VS/day/ft^3	% VS Reduction
I	4.6	5.13 (0.32)	41.9
III	3.7	7.37 (0.46)	29.1
III	5.0	6.41 (0.40)	36.0

* Waste Activated Sludge
** Primary Sludge

In the unpublished Cornell University ATAD digestion study two covered, well insulated pilot scale digesters were operated at about 2.5 days retention period each stage (Figure 25). This system used high efficiency atmospheric air aerators (oxygen transfer efficiency greater than 20%) to reduce the air flow through the units limiting evaporative heat loss so temperatures may be maintained in the 65°C to 70°C range. Investigations claim a stabilized sludge has been produced from this unit after 5 to 6 days retention time.

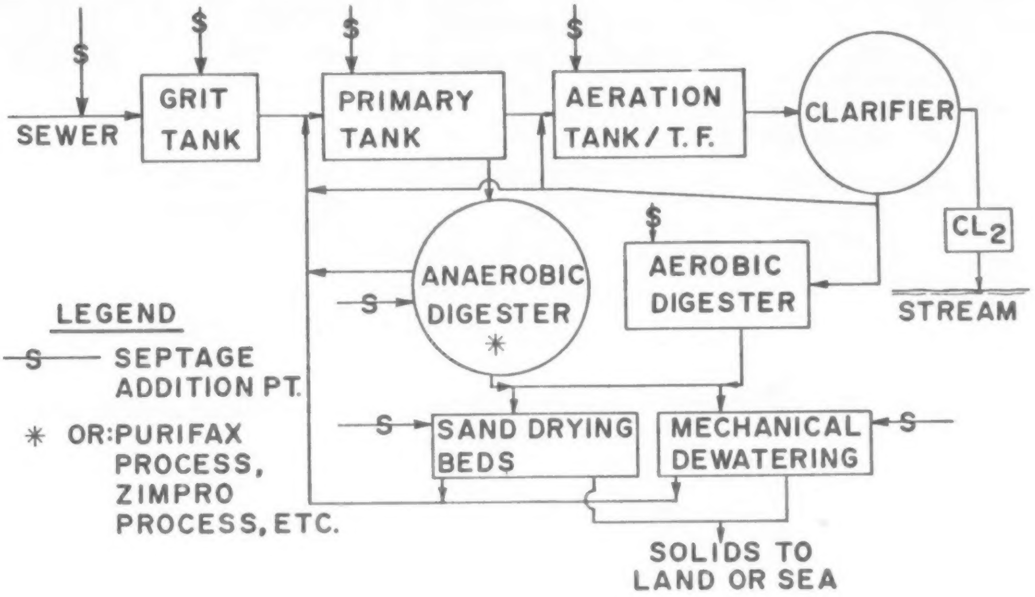

$
SEWER
GRIT TANK
PRIMARY TANK
AERATION TANK / T.F.
CLARIFIER
CL2
STREAM
ANAEROBIC DIGESTER
*
AEROBIC DIGESTER
S
SAND DRYING BEDS
MECHANICAL DEWATERING
SOLIDS TO LAND OR SEA
LEGEND
-S- SEPTAGE ADDITION PT.
* OR: PURIFAX PROCESS, ZIMPRO PROCESS, ETC.

Figure 25. Two stage pilot plant autothermal thermophilic aerobic digester (ATAD) system at Cornell University, Ithaca, NY.

SEPTAGE HANDLING AT SEWAGE TREATMENT FACILITIES

GENERAL HANDLING PROCEDURES

Septage can be disposed of in a STP by addition to either the liquid stream or the sludge stream. In either case, screening, degritting, and equalization are recommended.

Septage frequently is considered a high strength wastewater and is dumped into an upstream sewer or placed directly into various unit processes in a treatment plant (Figure 26). In several facilities, septage is considered a sludge because it is

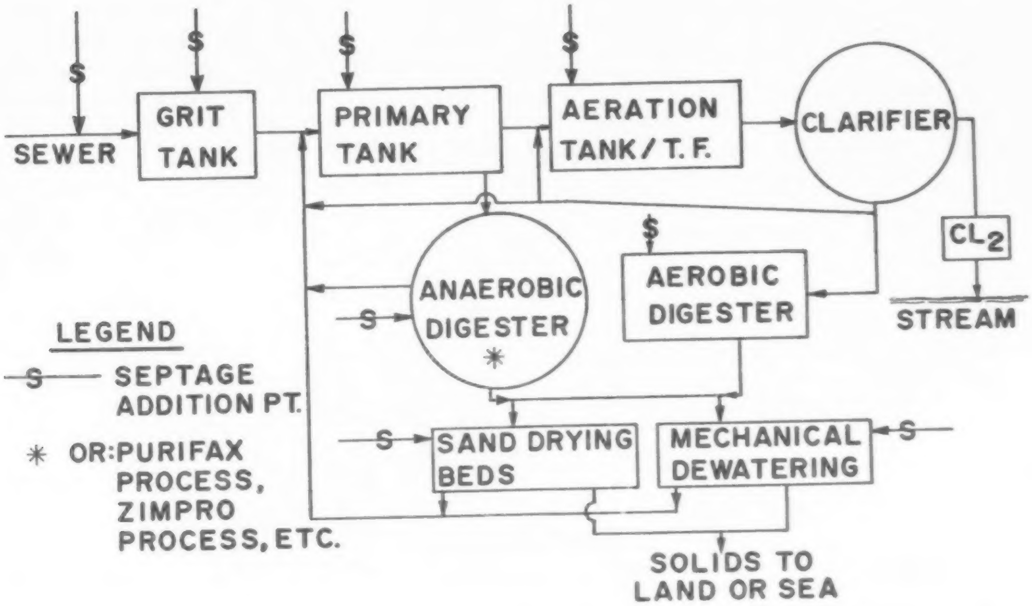

S
S
S
S
SEWER
GRIT TANK
PRIMARY TANK
AERATION TANK / T. F.
CLARIFIER
S
ANAEROBIC DIGESTER
*
AEROBIC DIGESTER
CL$_2$
STREAM
S
LEGEND
S SEPTAGE ADDITION PT.
* OR:PURIFAX PROCESS, ZIMPRO PROCESS, ETC.
S
SAND DRYING BEDS
MECHANICAL DEWATERING
S
SOLIDS TO LAND OR SEA

Figure 26. Septage addition points in septage treatment facilities.

the product of an anaerobic settling/digestion tank, and it has approximately the same total solids concentration as primary municipal sludge. The septage application points in the solids processing stream of an STP may include sludge thickening, stabilization, and dewatering steps. The decision of where to apply the septage should be determined following a statistically significant sampling and analysis program of a locale's septage for at least a theatre of seasons, including:

- solids loading
- oxygen demand
- toxic substances
- foaming potential
- nutrient loading (N and P), where required.

The above factors, combined with a plant's layout, design capacity, present loading, and the following design criteria provide the design professional with sufficient information to arrive at a reasonable septage treatment scheme within a wastewater treatment facility.

Receiving Station

Whether septage is added to an upstream sewer or discharged at a treatment plant in either the liquid processing stream or the solids handling area, a suitable hauler truck discharge facility should be provided. (57) This facility should include a hard surfaced, sloping ramp to an inlet port to accept a quick-disconnect coupling directly attached to the hauler's truck outlet, (7) thus reducing odor problems significantly. Washdown water should also be provided for the hauler so spills may be cleaned up. A recording of the time, volume, and name of the hauler is vital for both operation and billing purposes.

A schematic of the Barnstable, MA septage receiving station is shown in Figure 27. Portland, OR's Columbia Avenue plant septage receiving site is shown in Figure 28, while Seattle Metro's Renton STP septage receiving site is illustrated in Figure 29. The latter two sites use a plastic card or magnetically enclosed card and card reader to assist in management functions. The operator at the Portland facility validates a receipt with a charge card issued by the facility to each hauler certified to dump in that plant, while in Renton, the hauler places his identification card in an automatic card reader which relays information to the control center. A hard copy is retained for billing purposes. In addition, a buried loop and control circuit under the roadway at the Renton dump station causes a signal to register at the control center alerting the plant operator that a hauler truck has entered the dump station area.

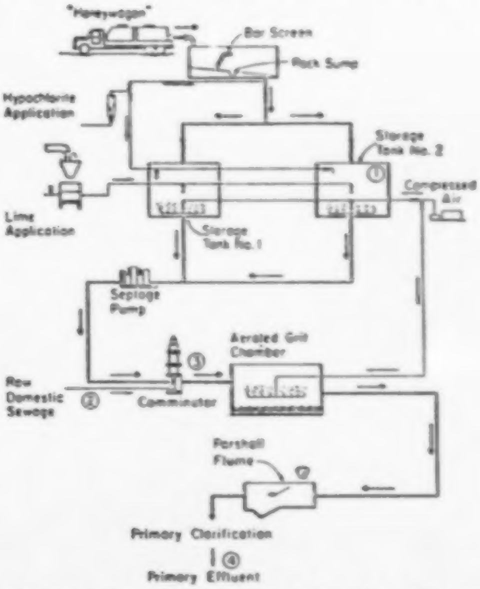
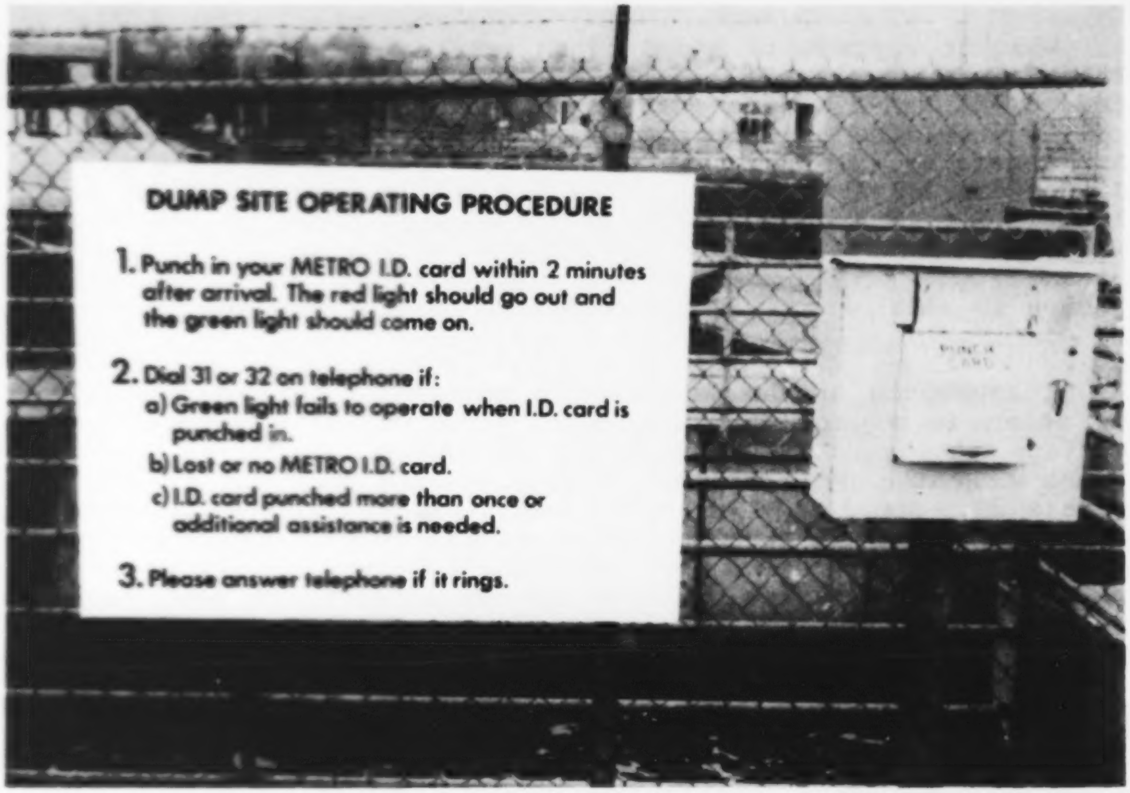

"Honeywagon"
Bar Screen
Rock Sump
Hypochlorite Application
Storage Tank No. 2
①
Compressed Air
Lime Application
Storage Tank No. 1
Septage Pump
Aerated Grit Chamber
③
Raw Domestic Sewage
②
Comminutor
Parshall Flume
Primary Clarification
④
Primary Effluent

Figure 27. Schematic diagram of the Barnstable, MA septage receiving station.



DUMP SITE OPERATING PROCEDURE

1. Punch in your METRO I.D. card within 2 minutes after arrival. The red light should go out and the green light should come on.
2. Dial 31 or 32 on telephone if:
   a) Green light fails to operate when I.D. card is punched in.
   b) Lost or no METRO I.D. card.
   c) I.D. card punched more than once or additional assistance is needed.
3. Please answer telephone if it rings.

Figure 28. Punch card reader at Seattle Metro's Renton STP.

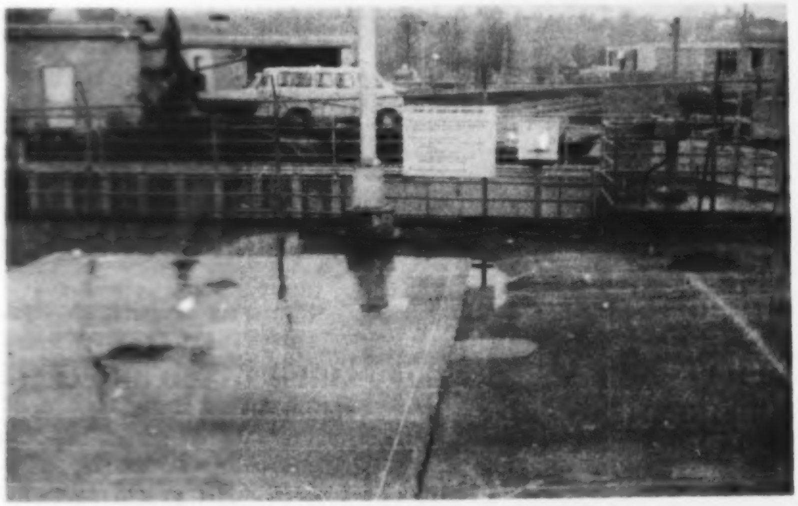


Figure 29. Septage receiving station at Renton, WA.

Pretreatment

Treatment plants handling septage have experienced better operation when septage pretreatment is employed. Pretreatment generally includes bar screens of 1.9 to 2.54 cm (3/4 to 1 in) opening, grit removal, and usually pre-aeration or prechlorination in aerated grit tanks along with the sewage flow for odor control if septage is added to an aerobic process. Grit removal by cyclone classifiers was designed into the Babylon plant and is included in the new Bay Shore plant, both on Long Island, NY. Separation of inorganic matter larger than 150 mesh can be achieved with currently marketed equipment. (58, 59) Equalization in 2 day average septage flow storage tanks and mixing capability should also be provided. To further attenuate odors, enclosed storage tanks, ozonation, activated carbon adsorption, or use of a soil filter to purify vent gasses exiting from perforated vent lines shallowly buried may be considered. The occurence of odor problems is sporadic, and degree of control should be related to proximity to dwellings, roads, other buildings, as well as prevailing wind patterns. Transfer pumping equipment should be used to apply a continual adjustable small dose of septage into the desired unit process from the storage tanks. Operators report slug doses or intermittent doses of septage are not as effective as a continuous feed rate. (60)

LIQUID STREAM PROCESSING

The following liquid stream processes were found to be capable of treating septage. They include primary treatment, slug (random mode) dumping, controlled (or continuous) feed into activated sludge units, and attached growth systems including trickling filters and rotating biological discs.

Primary Treatment--

The report by Feige et al. for the U. S. EPA indicated that neither natural settling, lime addition, nor polyelectrolyte addition resulted in consistent liquid-solids septage separation. (15) Tilsworth characterized raw septage as relatively non-settleable, as determined by a settleable-solids volume test. Results ranged from 0 to 90% settleable by volume, with an average of 24.7%. (12)

In an unpublished study at the University of Massachusetts, A. Tawa found septage settling characteristics could be divided into 3 groups, types 1, 2, and 3. Type 1, from septic tanks pumped before necessary, settled well. Type 1 septage was found in approximately 25% of his samples. Type 2 septage, from normally operating systems, showed intermediate settling characteristics and was found in 50% of his samples. Type 3 septage exhibited poor settling, was found in 25% of his samples, and was from tanks overdue for pumping. It was generally found that poor settling characteristics can be expected from septage. All samples were between 1 and 6 years of age.

It is generally accepted that septage settles very poorly without chemical addition. Tilsworth reported in his Alaskan septage study, 50% of the samples exhibited sludge interface height reductions of only 10% when allowed to settle for 30 minutes (Figure 30). About 1/3 of the samples are not shown in the figure, since they settled less than 1% of the original height. (12)

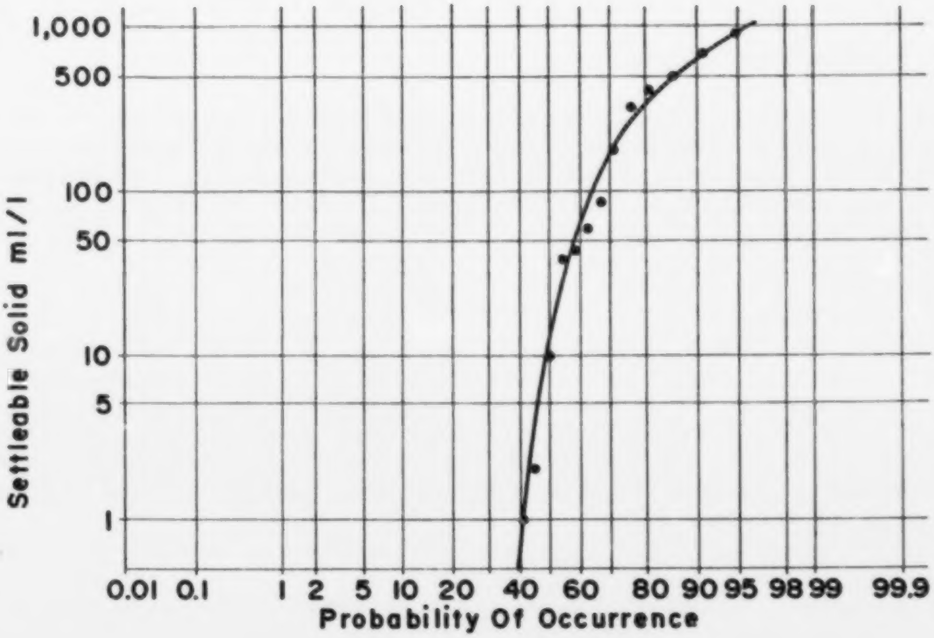


Figure 30. Probability of reduction of solids-liquid interface height after 30 minutes settling of Alaskan septage samples.

Elutriation, or settling of septage in a septage-sewage mixture, is reported to yield better results than attempting to settle pure septage. Smith and Wilson report that up to 60% of septage SS can be expected to settle in a STP's primary sedimentation basins. (61) An EPA study found 55 to 65% SS removals in a primary clarifier, while only 15 to 25% BOD removals resulted in the same unit process. (62) An EPA sponsored septage treatment project is currently underway at a Falmouth, ME STP, investigating pretreatment and liquid-solids separation techniques by the additions of various chemicals including Cl, Fe, Mg, Al, and acids; heat, and various combinations of these approaches. (96)

Activated Sludge--

Septage may be added to the activated sludge process if 1) additional aeration capacity is available, 2) the plant is hydraulically loaded below design capacity, 3) the septage metals content can be diluted to a sufficiently low concentration, 4) foaming potential can be controlled by sufficient dilution and 5) excess sludge handling capacity is available. Very limited quantities of septage may be added without changing the sludge wasting rates.

Slug Dumping--

Slug, or random mode dumping, occurs at a majority of the STPs which accept septage. Because of the dilution effect when mixed with raw sewage, it is suitable only for medium to large (2.0 mgd or greater) treatment plants. CH_2M/Hill recommended to the Forest Service that levels of septage and vault toilet wastes that can be added to differing types of activated sludge plants. (63) Vault toilet waste volumes are more critical than septage due to the effects of the 2 principal preservatives used in vault toilets - formaline and zinc sulfate. In an acclimated biomass, formaline may be added until an aeration basin level of 200 mg/l is reached, however with slug dumps, the level should not be raised to higher than 50 to 100 mg/l. (63) Zinc additions, however, should be limited to an aeration basin concentration of 5 to 10 mg/l on a continuous basis, but should be much lower in the slug dumping mode. Formaline is biodegradable and will not accumulate in sludge solids whereas Zn will accumulate rather quickly (over 90% in the first few hours) in the sludge solids. (64) This information, modified by the author's field investigations, is presented in Figure 31.

The use of slug dumping of septage may depend on limiting the increase in MLSS to 10% per day to maintain a relatively stable sludge, as seen in Figure 31. Higher loadings and wasting rates than the resident aquatic biomass is acclimated to may result in a poor settling sludge. (13) Severe temporary changes

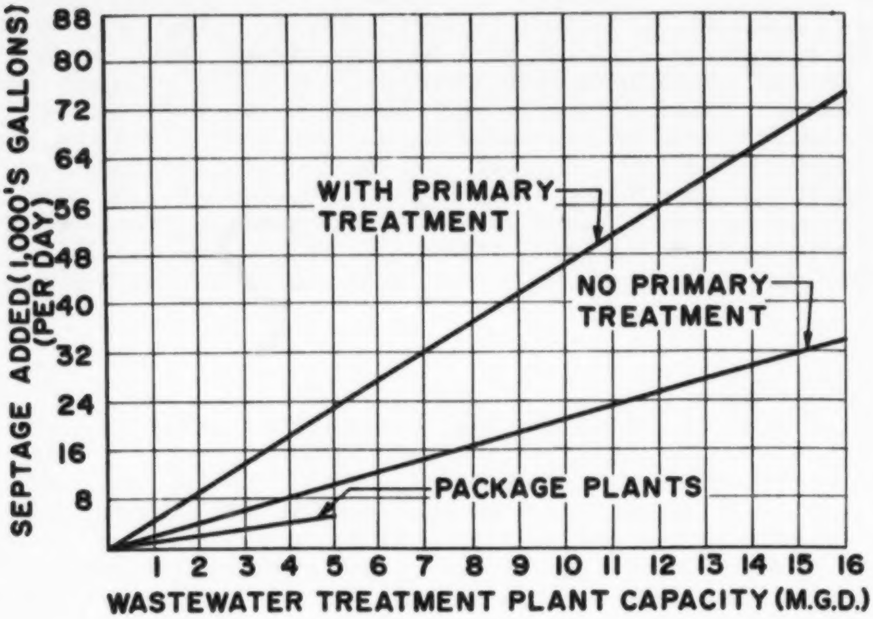


Figure 31. Volumes of septage addition to activated sludge wastewater treatment plants (no equalization facilities).

in loading beyond the 10 to 15% MLSS increase may cause a total loss of the system's biomass, while loadings below this level usually do not cause upset conditions. For example, the Weaverville wastewater treatment plant in Trinity County, CA, reports 400 GPD slug dumps could be handled at a 0.5 MGD plant operating at 40% capacity. (61)

In the slug dumping mode, package treatment plants should not be allowed to accept any septage if their design capacity is less than 100,000 gpd. (7) Most package plants of this size or less do not have grit removal, and without this process, grit accumulations in the treatment units may occur. Package treatment plants can be expected to treat septage at approximately 0.1% of the plant design capacity, since many package plants have been designed with minimal excess flow and treatment capacity compared to larger, built-in-place plants. This trend is now reversing as package plants are designed on excess flow criteria identical to larger plants. Modified activated sludge plants may treat septage at twice the rate of a package plant. (63) Conventional activated sludge plants are able to treat septage at about 4 times the rate of package plants and at about twice the rate as modified activated sludge plants. A large percentage of solids (25 to 60%) may be removed in the conventional plant's primary settling unit, normally lacking in a modified (contact stabilization or extended aeration) activated sludge plant, which accounts for the increased treatment capacity.

Controlled Addition---

In plants with holding and metering facilities, septage may be bled into the waste flow stream at considerably greater flows than would be attainable if only slug dumping procedures were available.

A U. S. EPA study fed septage at loadings of 2 to 13% of the sewage flow to 1 of 2 activated sludge units. (62) With a control unit F/M ratio of 0.4 and a septage-sewage F/M of 0.8, effluent BOD_5 and SS characteristics were similar. Effluent COD of the unit receiving septage increased almost in direct proportion to the rate at which septage was loaded. When a lower F/M ratio of 0.5 to 0.6 was utilized in the septage unit, this unit had superior performance due to control of Nocardia, a procaryotic filamentous actinomycete, often associated with bulking, and indigenous to the Blue Plains facility. (65)

Figure 32, showing volumetric feed rates of septage on a controlled basis to various types of treatment facilities, was developed from mass balances in various research reports, plus field investigations. Again, package plants with design capacities under 379 m^3/day (100,000 gpd) should not be allowed to accept septage because of their historic lack of ability to treat flows in excess of their design flow and loading capacity. (7) For example, the State of Maine does not allow septage addition at treatment facilities under 1,140 m^3/day (0.3 mgd). (66) Depending on the present plant flow compared to the design plant flow, a biological treatment reserve can be estimated which will allow for a certain level of septage to be adequately treated. With identical plant design capacities, the allowable relative volumes of septage addition to various types of treatment schemes flowing at various levels of design flow would be as follows.

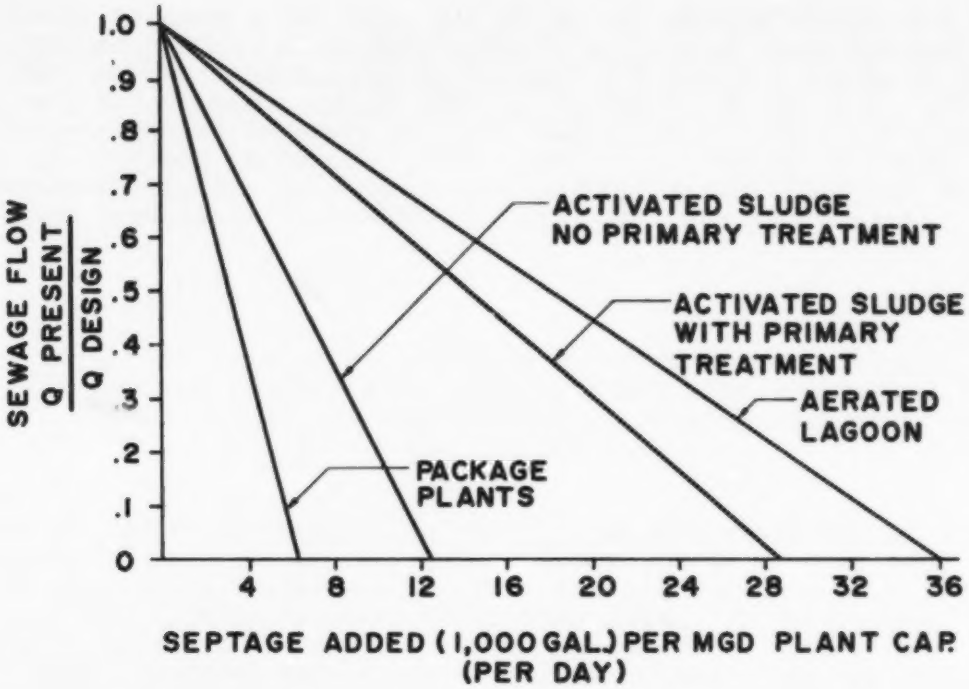


Figure 32. Septage addition to wastewater treatment plants with equalization facilities.

The limiting ratios of septage addition in Table 19 are based on 1) package plants having a limited ability to treat both flows and waste loadings beyond design capacity, 2) activated sludge treatment facilities without primary sedimentation treating all solids in aeration tanks, and 3) aerated lagoons usually having a long detention time (days) with which to buffer septage flows. (7) Figure 31 is indicative of continuous septage addition to a facility with a fully acclimated biomass. An initial septage feed to an unacclimated system should be substantially less than shown on the graph, and on the order of 10% of the graph values. Further gradual increases should be made in the range of 5 to 10% of the current septage flow per day up to the maximum amount shown in Figure 31. Dissolved oxygen must be checked continuously and gradual changes made in sludge age for optimum performance.

TABLE 19. RELATIVE VOLUMES OF SEPTAGE ADDITION TO VARIOUS PLANT SCHEMES OF IDENTICAL DESIGN CAPACITY

Package Plants	1.00
Activated Sludge (no primary treatment)	2.08
Activated Sludge (conventional)	4.83
Aerated Lagoons	6.00

In a recent study at the University of Massachusetts, feeding various volumes of septage to both batch and continuous flow complete mix activated sludge systems, the following empirically developed relationship between biological growth and substrate utilization were found to be applicable. (17) These models can predict volumes of septage that may be added to an existing facility if treatability studies of the service area's septage are undertaken to determine waste loadings and utilization rates:

$$dX/dt = Y\ dF/dt - k_d X \qquad 10$$

The rate of substrate utilization of the above expression, that is dF/dt, can be approximated by the following equation:

$$dF/dt = kXS/(K_s + S) = dS/dt \qquad 11$$

where dX/dt = net growth of bacterial cells, mass/volume-time.

Y = growth-yield coefficient, mass of cells/mass of substrate utilized.

dF/dt = rate of substrate utilization by bacterial cells, mass/volume-time.

k_d = bacterial decay coefficient, time^{-1}.

X = concentration of bacterial cells, mass/volume.

k = maximum rate of waste utilization per unit weight of bacterial cells, time^{-1}.

K_s = waste concentration at which rate of waste utilization is one-half the maximum rate, mass/volume.

S = waste concentration surrounding the bacterial cells, mass/volume, which is the waste concentration in a complete-mixing continuous flow reactor.

Dividing both side of Equation (10) by X, gives

$$(dX/dt)/X = Y(dF/dt)/X - k_d. \tag{12}$$

On a finite mass and time basis, Equation (12) becomes

$$(\Delta X/dt)_m/X_m = Y(\Delta F/\Delta t)_m/X_m - k_d. \tag{13}$$

where the subscript m represents a definite mass of bacterial cells. In Equation (13), the reciprocal of the term $(\Delta X/dt)_m/X_m$ is often referred to as the "sludge age", and will be designated as θ_c.

$$\theta_c = X_m /\Delta X/ \Delta t)_m \tag{14}$$

The term $(\Delta F/ \Delta t)_M/X_M$ is commonly knows as the food-to-microorganism (F/M) ratio, and will be referred to as U,

$$U = (\Delta F/ \Delta t)_m/X_m \tag{15}$$

Utilizing Equations (14) and (15), Equation (13) can be rewritten as:

$$1/\theta_c = YU - k_d \tag{16}$$

and Equation (11) can be rewritten as:

$$U = kS/(K_s + S) \tag{17}$$

By the principles of mass balance, Equations (16) and (17) will model both batch reactors and complete-mixing continuous flow reactors under steady-state conditions. These are conditions that will occur with continuous feed of septage to an aeration system.

Solving Equations (16) and (17) for S, gives:

$$S = K_s\ (1 + k_d\, \theta_c)/\ \ \theta_c(Yk - k_d) - 1 \tag{18}$$

and

$$S = UK_s/(k - U) \tag{19}$$

The kinetic coefficients Y, k_d, k, and K_s, which relate effluent substrate concentration, S to θ_c and V can be determined in laboratory-scale batch reactors or complete-mixing continuous-flow reactors.

The efficiency of waste treatment can be defined as:

$$E = 100(S_o - S)/S_o \qquad 20$$

where:

E = efficiency of waste treatment, percent

S_o = influent substrate concentration

S = effluent substrate concentration of waste

The rate of substrate utilization, dF/dt, can be expressed on a time related basis as:

$$\Delta F/\Delta t = (Q/V)(S_o - S) \qquad 21$$

where:

Q = flow rate, volume/time

V = volume of reactor

By utilizing Equations (15) and (21), and setting V/Q equal to θ, or the liquid retention time, the following equation is obtained:

$$U = (S_o - S)/\theta X \qquad 22$$

Substituting U from Equation (22) in Equation (16) and solving for X, gives:

$$X = \theta_c Y(S_o - S)/\theta(1 + k_d\theta_c) \qquad 23$$

which can be used to calculate the aeration system's concentration of bacterial cells. (17) With a known concentration of septage and empirically determined degradation rates, an existing facility can be optimized for sludge age and MLSS to obtain a U, or F/M ratio that will treat a septage-sewage mixture to the desired effluent concentration.

Feng has shown higher sludge ages (10 days vs 4 days) results in higher percentage BOD_5 removals and less sludge production than at the lower sludge age (17) (Figure 33). Wasting must be adjusted gradually with increased loads to obtain a sludge age which produces the optimum between aeration tank efficiency and good settling characteristics. A high sludge age produces a light sludge with poor settling ability but good substrate removal characteristics. The reverse is often true for a very young sludge. (7)

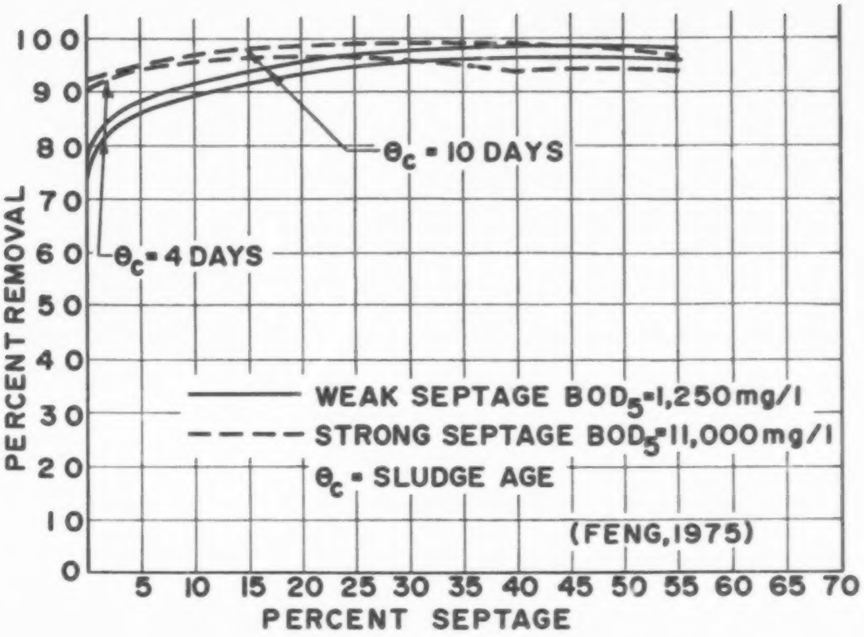


Figure 33. BOD_5 removal from septage-sewage mixtures in batch activated sludge process.

Figure 34 shows the additional oxygen requirements for septage addition in activated sludge treatment plants and is modified upwards from field experience. (63) Oxygen requirements usually exceed mixing requirements.

Because of the higher oxygen demand for septage than for raw sewage, an additional oxygen supply for activated sludge plants accepting septage having primary treatment would be 4.8 kg O_2/m^3 (40 lb O_2/1,000 gal) septage added. For plants without primary treatment, an additional 9.6 kg O_2/m^3 (80 lb O_2/1,000 gal) septage added should be provided. Package treatment plants will have an oxygen requirement similar to plants without primary treatment. (63) Feng has shown similar oxygen requirements in septage-sewage mixtures ranging from 0 to 40% septage in the mixture. At 40% septage, the mixture requires 4.3 times the volume of oxygen as would an influent with no septage in it. (17)

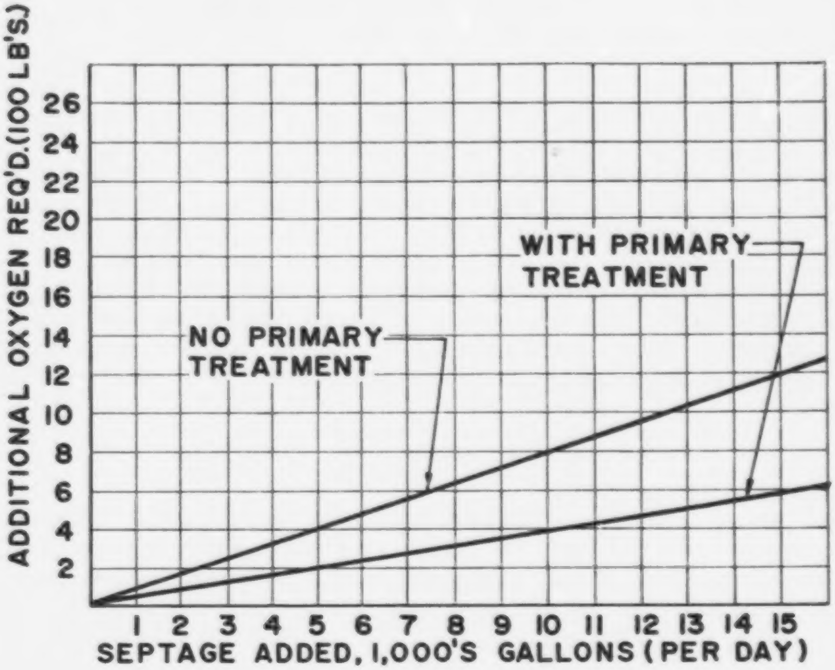


Figure 34. Additional oxygen requirements for septage addition to activated sludge wastewater treatment plants.

At one plant in suburban Long Island, NY, septage is bled into the liquid stream inversely proportional to the sewage flow. This procedure takes advantage of a larger excess aeration capacity lower loading times (7). An Orange County, FL STP added septage proportionately with sewage flow rates to dilute influent septage concentrations. Both plant's operators have experienced some operational problems. When septage is added inversely proportional to sewage flow variations, odor and floatable solids problems have been reported, but if septage is added proportionately to flow, an inferred oxygen deficiency can result. (67)

Some odor and foaming problems have been reported in aeration systems, however, the odor usually dissipated within 6 to 24 hours as freely strippable odor components of septage were separated from the material. (48, 11) Foaming was not apparent in all cases. Commercial defoamers, decyl alcohol, heat grids, foam fractionation, ozonation, aeration tank spray water, and increased aeration tank freeboard have been used in various studies and at various treatment plants on an exploration basis to reduce foaming with septage addition, all with limited success. (68, 67, 36, 69, 16, 13, 70, 97)

The United States EPA is sponsoring a contract study at the University of Lowell, MA, titled, "Monitoring Septage Addition to Wastewater Treatment Plants" to evaluate the effects of septage addition to secondary wastewater treatment facilities. Information to be presented includes effects of slug and continuous addition of septage on unit processes and overall plant performance, recommended septage loading rates to biological processes, recommended operational control strategies for plants treating septage, and estimates of both additional costs for treating septage and additional operation and maintenance requirements.

Attached Growth Systems--

Systems that employ attached growth aerobic treatment processes, such as trickling filters and rotating biological contactors, are usually more resistant to upsets from changes in organic or hydraulic loadings and are suitable for septage treatment. (54, 10, 71)

In trickling filters, additional recirculation has been shown to adequately dilute septage concentrations and diminish chances of plugging the media. At Huntington, Long Island, 114 m^3 (30,000 gpd) of septage is treated at a 7,200 m^3/day (1.9 mgd) facility. (10) BOD_5 reductions of 85 to 90% have been observed concurrent with a SS reduction of 85%. (10) Screening and grit removal is important to prevent plugging of the trickling filter media. Results of treating septage in Huntington's Plant are shown in Table 20.

Rotating biological contactors utilize a long detention time and a continually rotating biological media that is reportedly resistant to upsets. (8) At Ridge, Long, Island, a BOD_5 reduction of 90%, COD reduction of 67%, and a TSS reduction of 70% has been reported. This installation utilizes flow equalization of a high strength waste. A surface loading of 0.04 m^3 flow/day per m^2 surface area (1 gpd/ft^2) produced these results.

SOLIDS STREAM TREATMENT

Various processes for treating septage in the solids treatment area of a STP are discussed in this section. They include aerobic digestion, anaerobic digestion, mechanical dewatering, and sand drying beds. These processes, along with other closely related treatment schemes that are applicable to a STP (but have been practiced at another type of facility and have been discussed previously), are shown in Figure 35 by asterisk. Those sludge processing unit operations not investigated for septage treatment are also shown.

TABLE 20. PERFORMANCE OF HUNTINGTON, NY TRICKLING FILTER WASTEWATER TREATMENT FACILITY ACCEPTING SEPTAGE

Sample		Raw Scavenger Waste	Influent Chamber (Combined Waste)	Primary Tank Influent	Secondary Effluent	% Reduction
1	BOD	5400	190	350	40	88.5
2	pH	6.1	6.9	6.8	6.8	
	BOD	1130	206	173	38	76.0
	COD		409	951	151	84.0
	TS	1132	509	730	325	55.5
	TVS		287	450	146	67.5
	SS		196	414	62	85.0
	VSS		160	338	34	90.0
	% TVS		56.5	61.5	45	
	% VSS		84.0	81.7	54.8	

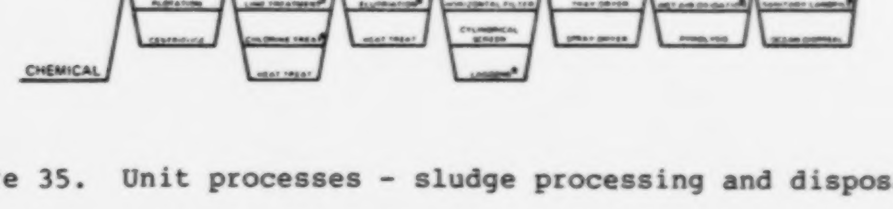

SLUDGE TYPE
THICKENING
Blending *
STABILIZATION
Reduction
CONDITIONING
Stabilization
DEWATERING
HEAT DRYING
REDUCTION
Stabilization
FINAL
Disposal
SEPTAGE*
PRIMARY
SECONDARY
CHEMICAL
GRAVITY *
FLOTATION
CENTRIFUGE
COMPOSTING *
AEROBIC DIGESTION *
ANAEROBIC DIGESTION *
LIME TREATMENT *
CHLORINE TREAT *
HEAT TREAT
CHEMICAL *
ELUTRIATION *
HEAT TREAT
FILTER PRESS
DRYING BEDS *
CENTRIFUGE
ROTARY VACUUM FILTER *
HORIZONTAL FILTER
CYLINDRICAL SCREEN
LAGOONS *
FLASH DRYER
MULTIPLE HEARTH
TRAY DRYER
SPRAY DRYER
INCINERATION
WET AIR OXIDATION *
PYROLYSIS
CROPLAND *
LAND RECLAIM *
POWER GENERATION
SANITARY LANDFILL *
OCEAN DISPOSAL

Figure 35. Unit processes - sludge processing and disposal.

Aerobic Digestion--

An alternative to considering septage as a concentrated wastewater would be to assume septage is the product of an unheated digester and, therefore, a sludge.

Many researchers have reported good results in both lab scale and pilot plant scale aerobic digestion of septage or septage-sewage sludge mixtures. Jewell reports diminished odors, but the time required to produce an odor-free sludge varied up to 7 days. (16)

Tilsworth reported a high degree of septage biodegradability at a 10 day aeration time, resulting in a BOD_5 reduction of 80% and a VSS reduction of 41%. (12) Chuang treated septage first in an anaerobic unit then with an aerobic digester, reported a 36% VSS removal in the aerobic portion at a 40 day aeration time under a loading of 0.03 $Kg/day/m^3$ (0.0016 lb VSS day/ft^3). (7) After 22 to 63 days aeration, Howley found a 43% VSS reduction and a 75% COD reduction. (36)

Septage-sewage mixtures are also amenable to treatment. Cushnie showed an average 98% BOD_5 removal from septage-sewage mixtures, ranging from 0% septage to 20% septage at 6 day's aeration. Orange County, FL, adds septage to aerobic digesters at the rate of 5% of the sludge flow and obtains good reductions at a loading of 2.4 kg $VS/ft^3/day$ (0.15 lb $VSS/-ft^3/day$). (67) Bend, OR, obtained good removal in a mixture containing 13% septage and 87% sludge at a loading of 0.32 kg $VSS/ft^3/day$ (0.02 lb $VSS/ft^3/day$), utilizing a 15 to 18 day aeration time. (68)

Tilsworth observed α and β gas transfer characteristics for septage and found that both α , the ratio of gas transfer efficiency to tap water, and β , the ratio of O_2 saturation concentration to tap water, approached unity after 1 to 2 days' aeration. Prior to 1 day, α and β were in the range 0.4 to 0.6. (12)

Jewell found both dewatering and settleability improved with aeration, but the aeration time required to effect significant improvement varied. (16) Two U. S. EPA studies are currently investigating septage addition to aerobic digesters. An inhouse study is underway at Lebanon, OH, and a contract study is being performed at Falmouth, ME.

Prior to adding septage to the aerobic digestion process, aeration capacity, toxic metal or chemical accumulations, and increased solids disposal should be investigated. All investigators consistently have reported repulsive odors and foaming problems (7, 67, 36, 69, 12) with foaming occuring as an indirect relationship with the use of detergents by the septic tank owners. (36) Most investigators report foaming diminishes after 24 hours.

Bend, OR (Figure 36) solved the overflow of foam from its aerobic digester with the addition of fiberglass panels for around the top of the digester for increased freeboard. Table 21 below shows time to change in odor and loss of foam from 11 Vermont septage samples. (24)

TABLE 21. TIME TO LOSS OF SEPTAGE ODOR AND FOAM REDUCTION FROM BATCH AEROBIC DIGESTER (36)

Batch Number	Time to Odor Change After Initiating Operation (days)	Time to Loss Of Foam (days)	Household Used Washer Detergent
1	4	9	Yes
2	9	10	Yes
3	4	13	Yes
4	3	19[FF]	Yes
5	10	12	Yes
6	5	No foam	No
7	5	6	Yes
8	1	--[FF]	Yes
9	No septic odor	14[FF]	Yes
10	3	7	Yes
11	3	11	Yes
Mean	4.7	10.9	
Median	4	10.5	

FF Batch 4 was foam fractionated after 19 days, batch 8 at start-up, batch 9 after 14 days.

Figure 36. Aerobic digester at Bend, OR STP.

Recommendations, when considering septage addition to aerobic digesters, should include screening, degritting, flow equalization, an analysis of excess digestion capacity, management scheme to reduce foaming problems, and peripheral effects to other processes such as solids handling. An initial septage addition should be limited to approximately 5% of the existing sludge flow. Further septage additions should be gradual.

Anaerobic Digestion

Septage in Tallahassee, FL, is treated in an unheated anaerobic digester which operates at 20°C to 30°C (7, 72) (Figure 37). With an influent septage concentration of 17,700 mg/l total solids, a VS reduction of 56% was reported after an 82 day retention time at a loading of 0.16 kg VSS/m^3/day (0.01 lb VSS/ft^3/day). Large quantities of grit in the septage required draining and cleaning of the open digester after only 3 years of operation. Leseman and Swanson analyzed the distribution and concentrations of volatile acids in the digester (72) and found volatile acid to alkalinity ratio varied from 0.34 to 0.83. The 8 month average volatile acid concentration was 703 mg/l and ranged from 408 mg/l to 1,117 mg/l at a consistent pH near 6.0. The progression of volatile acid concentrations in the digester, from 2 to 5 carbon acids, showed acetic = 276 mg/l, propionic = 294 mg/l, isobutryric = 14 mg/l, butyric = 49 mg/l, isovaleric = 28 mg/l, and valeric = 42 mg/l. Similar results are reported by Kolega in raw septage samples from Litchfield, CT. He found an average total volatile acid concentration of 807 mg/l, with acetic = 253 mg/l, propionic = 412 mg/l, isobutyric = 26 mg/l, butyric = 30 mg/l, isovaleric = 50 mg/l, and valeric = 36 mg/l. (27) Since Tallahassee's digester had an open cover, gas production could not be monitored. Supernatant from this digester is pumped to the sewage sludge anaerobic digester. Anaerobic digestion of septage is more likely to be successful than anaerobic digestion of night soil. Poor results have been experienced in the Orient, relating to scanty methane production, slow stabilization, strong supernatant liquid, and an odorous, poorly dewaterable product. (56)

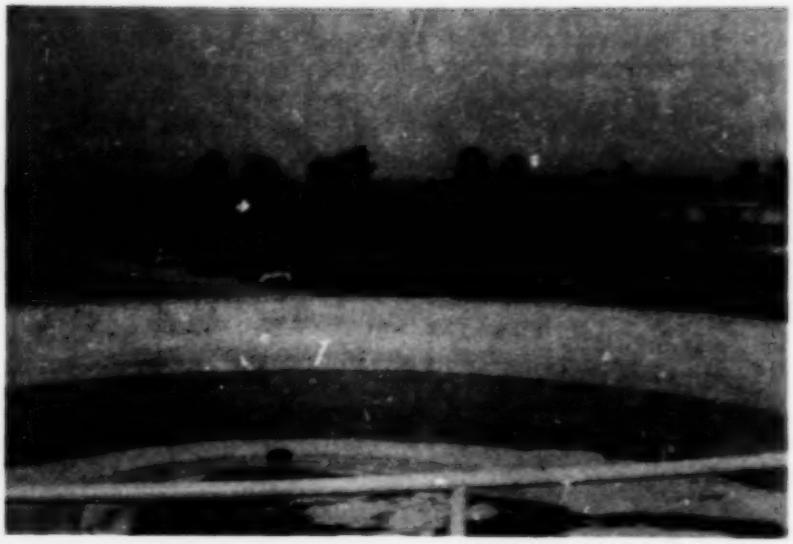


Figure 37. Anaerobic digester stabilizes septage at Tallahassee, FL STP.

Jewell reported a 45% reduction in VSS from a digester loaded at 0.80 kg VSS/m^3/day (0.05 lb VSS/ft^3/day), with a 15 day hydraulic retention time. Gas production varied from 0.26 to 0.47 m^3/kg COD_r (1.2 to 7.6 ft^3/lb COD_r), at a loading of 1.28 kg VSS/m^3/day (0.08 lb VSS/ft^3/day), where gas production fell off drastically, indicating a possible poisoning of the system by a toxic chemical concentration of unknown source. (16)

Chuang reported a 92% VSS removal from a heated anaerobic digester loaded at 1.28 kg VSS/m^3/day (0.08 lb VSS/ft^3/day) with a 15 day hydraulic retention time. (7) Incoming solids ranged from 0.3 to 8%, and total solids reduction was more than 93%. BOD reductions averaged 75%, from 6,100 mg/l in the influent to 1,500 mg/l in the effluent. Spohr found that when septage-sewage sludge was added to anaerobic digesters in Anne Arundel County, MD, no change in digestion was apparent if total solids in the digester were between 2 and 15%. (73)

Based on his research, Howley recommends a maximum septage addition of 8.1 m^3/day (2,130 gpd) to each 55 m^3 (14,500 gal) sewage sludge added per day per 3,785 m^3 (million gal) of digester capacity, with a detention time of 30 days and a maximum loading of 1.28 kg VSS/m^3/day (0.08 lb VSS/ft^3/day). (36) Good operation of anaerobic digesters requires a limitation on toxic materials. An inhouse U. S. EPA study on septage addition to anaerobic digesters is being performed at Lebanon, OH, and is expected to yield more precise loading information.

In single-stage digesters, prior treatment with screening, grit removal, and equalization is necessary. Digesters should be cleaned on a regular schedule, such as every 3 to 5 years, or as required. (74)

Monitoring digester performance includes long term evaluation of volatile acid/alkalinity ratios and gas production. Mixing is vital in preventing a sour digester from the propagation of point-source failure due to a septage load containing high volatile acid concentrations and low pH.

In systems with multiple digesters, in addition to all the preceding suggestions, the additional practices should be followed. Spreading the septage load to many digesters will reduce septage concentrations. Recycling from the bottom of a secondary digester or from another well-buffered primary digester at a rate of up to 50% of the total raw feed per day has been helpful. Control of temperature and mixing should also be adjusted for maximum performance. (74) A rule of thumb in adjusting temperatures says changes should not exceed 0.56C° (1F°) per day to prevent shocking an acclimated biomass.

Mechanical Dewatering

Islip, Long Island, uses a vacuum filter (Figure 38) to dewater 379 m^3/day (100,000 gpd) of chemically conditioned, settled septage. A design basis of 10 lb/hr/m^2 (5 lb/hr/ft^2) of surface area was used. A lime addition of about 0.1 kg lime/kg septage dry solids (190 lb/ton of dry solids) and 0.0002 m^3/ kg dry solids (50 gal/ton of dry solids) standard concentration ferric chloride solution are added prior to settling and vacuum filtration of the resultant sludge. (7)

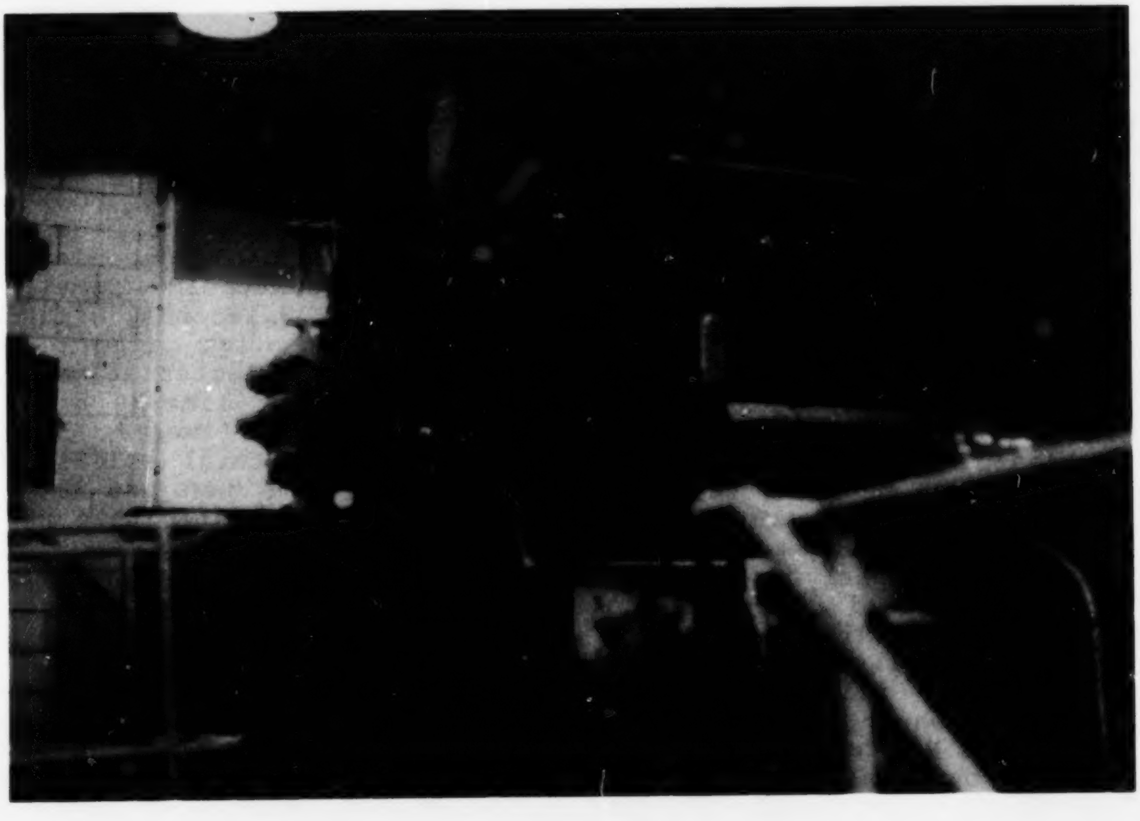


Figure 38. Islip, NY vacuum filter dewaters chemically conditioned septage.

In laboratory study at Clarkson College, Crowe obtained successful results with vacuum filtration of raw septage and mixtures of raw septage and digested sludge with up to 20% raw septage by volume. Chemical conditioning with 10 to 20 gm lime/100 gm dry solids, 5 to 25 gm ferric chloride per 100 gm dry solids, and 1 to 2 gm polymer/100 gm dry solids (Calgon WT2640) were investigated. Dewatering characterisics of chemically treated septage and septage-sewage mixtures were observed to be similar to the chemically treated digested sludge alone. The filtrate contained only 5 to 10% of the raw septage COD. (75) Attempts to vacuum filter untreated Alaskan septage met with limited success because of media plugging problems. Polypropylene 24 x 21, having a plain weave 1/1 gave the best filtration rates of any media tested, ranging from 4.88 to 26.07 $kg/hr/m^2$ (1.0 to 5.34 $lb/hr/ft^2$). Highest filtration rates were observed on samples with solids in the range of 0.5 to 1.0%. (12)

Sand Drying Beds

Sand drying has been used to dewater septage, but with varying success. Anaerobically digested septage is reported to require 2 to 3 times the drying period of digester sludge. (72) After 15 to 20 days treatment in aerated lagoons and batch aerobic digesters, dewatering simulation studies yielded a septage capillary suction time (CST) of less than 50 seconds. (76) CST values of conventional sewage sludge that can be readily dewatered in sand drying beds vary up to a maximum of 70 seconds. A lower CST can be correlated to a faster dewatering time. CST's of raw septage usually range from 120 to 825 seconds, with a mean of 200 seconds. (76) Lime addition of septage prior to sand bed dewatering vastly improved dewatering characteristics. Feige, et al, found that an addition of 0.09 kg lime/kg dry solids (180 lb lime/ton dry solids), or 3.59 kg $lime/m^3$ (30 lb lime/1,000 gal) septage based on 40,000 mg/l total solids, raised the pH to 11.5 and dried to 25% solids in 6 days and 38% solids in 19 days. (15) An application depth of greater than 8 inches is not recommended, because it slows the drying process. The filtrate analysis (Table 22) showed that 1) most heavy metals were tied up in the solids; 2) fecal coliform were reduced substantially, 3) fecal streptococci were more resistant than fecal coliforms; and 4) odors were significantly reduced. Some minimal filtrate treatment is necessary, however. (10) Lime addition in this study was lower than levels recommended in a Battelle Northwest study in which higher pathogen kills were obtained by raising the pH above 12. (15)

Perrin found other chemicals worked well in modifying the ability of septage to dewater. From a mean initial septage CST of 450 seconds, a CST of 50 seconds was realized after the addition of an average of either 1,360 mg/l ferric chloride, 1,260 mg/l alum, 1,360 mg/l Purifloc C-31 (cationic), or 2,480 mg/l Purifloc C-41. (76)

Crowe's laboratory study also found chemical addition greatly enhanced dewatering of septage and septage-sewage mixtures. Doses of 10 to 20 gms lime/100 gms dry solids, 5 to 26 gms ferric chloride/100 gms dry solids, and 1 to 2 gms Calgon WT 2640 polymer (cationic)/100 gms dry solids reduced initial CST of 400 seconds to less than 50 seconds. (75)

Perrin also studied the affects of freezing on dewatered samples of septage after treatment in aerated lagoon, or batch aerobic digestion. Freezing lowered the CST from an initial 225 seconds to 42 seconds, an 80% improvement in dewatering time. (76)

A U.S. EPA sponsored study at Falmouth, ME, will investigate septage treatment by conditioning and dewatering of septage with vacuum filters, filter presses, and centrifuges.

If septage is to be placed on sand drying beds, treatment to a consistent CST range of 50 to 70 seconds is recommended. Further treatment of underdrainage would be required in most cases.

SECTION VII

ALTERNATIVES EVALUATION

General

The purpose of this evaluation is to summarize key design and operating data, present advantages and disadvantages for each alternative, discuss relative economics of each process, and combine that information in a comprehensive evaluation and ranking of each alternative in order of preference in a socioeconomic, technical, institutional, and environmental framework.

Several methods of septage treatment and disposal have been presented. Each of these alternatives can be assigned to one of the following categories.

1. Land application
2. Treatment at a septage facility
3. Treatment at a STP

LAND APPLICATION

Presently, the authors estimate well over 75% of the septage generated in the United States is disposed of directly on the land. Chemical constituents of concern in this mode of disposal include heavy metals and nitrogen. Septage odors are a potential problem in determining land disposal sites, yet odors may abate within hours after thin land applications of septage. If nitrogen loadings to the soil are kept to level which will not promote buildup of nitrate concentrations in underlying groundwater, heavy metals will not be a major consideration. (78) Transmissibility considerations for various pathogenic agents that may be found in septage (viruses, bacteria, cysts of protozoans, and ova of helminths), suggests that some pretreatment of septage be accomplished prior to direct land disposal. (24, 22) A partial list of available pretreatment processes could include storage in aerated or non-aerated lagoons, lime addition to a pH 11.5 to 12, aerobic or anaerobic digestion, composting, wet air oxidation, pressure chlorination, or possibly processes not yet fully investigated, such as irradiation.

Land application techniques that do not require pretreatment processes include subsurface disposal and disposal in a sanitary landfill. Subsurface disposal requires more land on a N loading basis than direct application since no volatilization losses occur, but subsurface disposal is not as sensitive to precipitation events (which may lead to runoff problems) nor would odor problems be as apparent. Capital investment and labor is greater than direct application techniques, but savings may be reflected in systems without pretreatment requirements. Generally, surface application techniques are more acceptable in less densely populated regions, while subsurface disposal is practiced close to major population centers.

Septage disposal to sanitary landfills is practiced extensively in NJ, with application rates limited to 0.05 m^3 septage per m^3 solid waste. In order to minimize leachate production, many landfills prohibit the introduction of wastes with free water. Leachate collection and treatment facilities should be provided if septage is added to a landfill, but may not be needed if the landfill should be located so leachate water is prevented geohydrologically from entering the groundwater and no runoff of leachate is possible. Based on U. S. EPA Construction Grants sludge disposal cost data, septage disposal in landfills tends to be one of the more expensive methods encountered.

Lagoon disposal of septage is also one of the more common methods of disposal. The placement of septage in terminal drying lagoons is practiced in many states including Connecticut, New York, and Oregon. Free water will percolate through sides and the bottom until clogging occurs. Evaporation then removes much of the remainder of the free water. Solids are then bucketed to a landfill or the lagoon is covered with a soil layer. Massachusetts and other areas use lagoons followed by infiltration beds. Lagoons are sized to handle 20 days storage at average flows at a minimum depth of 1.8 m (6 ft). At least 6 percolation beds with a total effective area of 0.04 m^3/m^2/day (1 gal/ft^2/day) follow the lagoon. Groundwater considerations should be evaluated, and current requirements include the base of a lagoon being at least 1.2 m (4 ft) above maximum high groundwater, while the percolation beds should be at least 1.8 m (6 ft) above high groundwater level. As further protection for potable well water quality and odor control, a lagoon system should be a minimum of 305 m (1,000 ft) from any dwelling. Groundwater quality should be monitored to determine if degradation is occuring.

Total disposal costs of land based systems are estimated to be in the range of $1.50 to $5.00 per 3.8 m^3 (1,000 gal). (78)

A potential for a more cost-effective disposal system exists with the marsh/pond and meadow/marsh pond system. Although experimental, these systems are estimated to treat septage at about \$1.00/3.8 m^3 (1,000 gal). (832, 33, 77) Lagoon disposal facilities generally require site location in sparsely populated areas to provide buffer zones for odor dissipation and aesthetic camouflaging.

Separate Septage Treatment Facility

Separate treatment facilities account for a very small percentage of the total disposal volume at present, but the proliferation of these types of facilities in the future is probable as political forces motivate management decisions in these directions. (65, 14) These systems are applicable only where sufficient septage volume (over about 50 to 100 m^3/day or 13 to 26,000/gal day) is available in a local area. Such facilities will fulfill the requirements of pretreatment prior to land disposal or they will include complete treatment facilities with controlled effluents and solids disposal to the land. This category also includes composting, which yields a useable, marketable end product.

Systems employing aerated lagoons for treating septage and other high strength wastes followed by settling lagoons typically show BOD removals in excess of 90% with aeration retention times over 4 days. Aerated lagoons have been shown to work better when grit removal and buffering and equalization of at least one days average flow are provided. Odors have been found to dissipate within one day, but foaming is frequent and hard to control. Various methods have been tried, including defoamer addition, heat grids crossing the tops of the units, and sprays. More work is needed to develop effective anti-foaming techniques. Effluents from these systems may require further treatment, such as application to infiltration beds or land based disposal, such as spray irrigation. Solids may be hauled for disposal in a sanitary landfill or diposed of on the land. Total costs for aerated lagoon systems are in the range of \$5.00 to \$10.00 per 3.8 m^3 (1,000 gal). (78) Costs for further treatment must be added to these costs.

Chemical addition to septage in clarifiers will sometimes achieve liquids-solids separation. Good results have been noted with various combinations of lime (about 10,000 mg/l), ferric sulfate (4,000 mg/l), ferric chloride (0.0002 m^3 standard strength solution/kg dry solids), and varying amounts of cationic polymers. Previously, clarifiers based on typical sewage overflow rates have been undersized, with significant solids carryover occurring at 25 m^3/day m^2 (600 gpd/ft^2). U. S.

EPA sponsored research is underway at Falmouth, ME to determine suitable overflow rates. Underflow solids have successfully been dewatered on vacuum filters with yields of 2 to 4 kg/m^2/hr (0.4 to 0.8 lb/ft^2/hr. Odor and foam are insignificant problems and operation is not affected by climatic changes. Due to the shear bulk of chemicals needed, disposal costs for this process can excees $30.00/3.8 m^3 (1,000 gal). (78)

An adjunct to chemical precipitation is chemical stabilization. Enough lime (3.6 kg/m^3 or 30 lb/1,000 gal) is added to raise the pH to 11.5 to 12 to kill bacteria and stabilize the waste. Coliforms are readily killed, but streptococi are more resistant. Virus inactivation and ova and cyst survival need to be addressed. Costs for chemical stabilization can be in excess of $30.00/3.8 m^3 (1,000 gal). (78)

Pressure chlorination of septage results in a material that is easily dewatered, possesses a medicinal odor, and is stabilized from further bacterial action. Chlorine consumption accounts for a significant amount of the $15.00 to $50.00/3.8 m^3 (1,000 gal) treatment cost. (78) Typical dosages of chlorine are in the range of 700 to 3,500 mg/l chlorine at 241,000 pascals (35 psig). The occurance and significance of chlorinated hydrocarbons that may be associated with this technique are being investigated by the U. S. EPA.

Composting of septage has been practiced almost exclusively in Washington State with the Lebo process. Aerated septage is mixed with sawdust until the mixture has a 50 to 60% moisture content. After three months, bacterial concentrations have been greatly reduced and organic carbon conversion has occurred. A market needs to be further developed for the soil amendment residual of the compost process. Site preparation is necessary to prevent runoff of leachate or rainfall runoff. The process location need not be significantly separated from dwellings for consideration of odors, as composting is an aerobic process and is inherently less subject to odor problems than anaerobic processes. Costs for composting are in the $7.00 to $30.00 range per 3.8 m^3 (1,000 gal). (78)

Autothermal thermophilic aerobic digestion (ATAD) is still experimental, but may prove cost-effective as a digestion technique for septage as well as sludge solids. (53) Reaction time in two stage insulated aerobic digesters is cut to 2.5 days/unit, vastly lowering unit sizing and associated capital costs. Foaming will be apparent, as it is in any aerobic process.

Treatment costs may be about \$15.00/3.8 m^3 (1,000 gal), but further treatment or disposal costs should be added.

Facilities have been proposed for separate septage treatment using rotating biological contactors (RBC) preceded by either anaerobic digestion or clarification. Experience with other high strength waste has shown a total disc area of 24.4 m^2/m^3 septage applied is required. The liquid phase would require additional treatment, such as sand filtration, while solids would be disposed of on land after dewatering. Total capital and operation and maintenance costs for this process are estimated to be between \$28.00 to \$32.00/3.8 m^3 (1,000 gal) in 1975. (8) Solids disposal costs must be added to these figures. If the units are enclosed, odors should not present a problem, and foaming would be significantly less than in a forced aeration unit.

Sewage Treatment Plant

Septage addition to a STP includes either addition to the incoming municipal wastewater flow or to the solids processing area. In either case, additional sludge solids will accrue from the septage addition. For example, plant operators at the Columbia Avenue Treatment Plant in Portland, OR have found the addition of 1 m^3 (264 gal) of 5% solids septage will result in an additional 1 m^3 (264 gal) of 0.5 to 1% waste activated sludge plus an undetermined amount of primary sludge. Research studies at the University of Lowell, MA are underway with emphasis on resolving both sludge production questions and what limits of stress several types of biological systems will accept in order to determine the consequences of varying levels of septage addition to wastewater treatment plants.

Direct addition of septage without pretreatment at a point in the sewer upstream or at the head of a treatment facility results in potentially upsetting slug organic loads to a biological process as well as accumulations of large volumes of grit and extraneous material which may cause clogging and accelerated equipment wear. Large treatment facilities (over 379,000 m^3/day or 100 MGD) usually handle infrequent (less than 0.01% of the daily flow) slug dumps of septage, but smaller plants accepting septage have shown a trend towards installing screening, degritting, and blending pretreatment facilities to meter septage to the plant on a controlled basis.

The key requirement of a treatment facility is to maintain required effluent quality. The regime which places the least stress on effluent quality is typically septage addition to the solids processing system rather than the sewage flow scheme, providing excess capacity is available. Potentially, more septage could be handled in the sludge processing system than by addition to the liquid flow due to the tendency for septage to be higher in solids concentration than waste activated sludge.

Septage has been shown to dewater poorly. Approximately 40 - 60% of SS can be expected to settle in the primary facilities if septage is added to the mainstream flow. The remainder of the solids, plus soluble BOD_5 is added to the aeration units for conversion to solids. These secondary solids are lighter and bulkier than septage. Consequently, more incremental sludge flow to the digesters can be expected when septage is added to the liquid stream than when it is added directly to the solids processing area.

The degree of septage treatment in aeration facilities depends on the degradability of the waste and the excess aeration capacity available. Present information concludes septage is highly amenable to aerobic treatment, but excess aeration capacity is crucial to BOD_5 removals. Slug dumping imposes heavy organic shock loads, and should not be practiced, since the rapid increase in sludge mass may make the sludge unstable. The likelihood then exists for a washout of sludge solids over the final clarifier weirs. Additional oxygen is required to treat septage, and varies from 18 to 36 kg $O_2/3.8\ m^3$ (40 to 80 lb O_2/1,000 gal).

Odor control and foaming problems are endemic to septage treatment in aerated systems. Fortunately, various methods of foam control are currently available, such as spray water, defoamers, and foam fractionation, but more work needs to be performed in this area. Costs for treating septage at a STP typically are $10.00 to $20.00 per 3.8 m^3 (1,000 gal) but individual plants have reported costs significantly higher and lower than this commonly seen range. (78)

Most treatment plants accepting septage utilize either aerobic or anaerobic digestion followed by sand bed dewatering or vacuum filtration. Few used other processes, such as chemical oxidation or wet air oxidation and incineration.

Anaerobic digestion treating septage must be closely monitored, since the high volatile acids concentrations of septage may lead to failure conditions. This method eliminates the foaming and odor problems found in aerobic units, but high septage loadings may introduce critical concentrations of heavy metals, surfactants, or toxic organic compounds (especially if vault toilet or recreational vehicle toilet pumpings are included) that may upset digester performance. Loadings of septage in excess of 1.28 kg VSS/m^3/day (0.0816 lb VSS/ft^3/day) resulted in a drastic drop in anaerobic digester gas production. (16) Anaerobic digestion also increased dewaterability of septage, but it will still dewater slower than anaerobically digested sewage sludge.

Aerobic digestion of septage has been successfully demonstrated in various locales, but major problems stem from foam production and to a lesser extent, odor. One successful method of foam control is to increase available freeboard from a standard 0.5 m (18 in) to 1.2 m (48 in) or more. Aerobic digestion of septage, demonstrated at rates from 0.48 kg VSS/m^3/day (0.03 lb VSS/ft^3/day) to 20.8 kg VSS/m^3/day (1.3 lb VSS/ft^3/day), has been successful in improving dewaterability. Costs for treating septage by anaerobic or aerobic digestion predominantly fall in the range from $5.00 to $15.00 per 3.8 m^3 (1,000 gal), including pretreatment facilities. (7)

Other methods are available for increasing the dewaterability of septage, but they have significant drawbacks. The U. S. EPA has successfully demonstrated liming septage to a high pH (11.5 to 12), but costs are excessive compared to other systems (over $26.00 per 3.8 m^3 (1,000 gal)). (7)

Other additives, such as cationic polymers and ferric chloride will significantly improve septage dewatering, but their costs, too will be excessive based partly on the high concentrations of chemicals required. These methods also do not insure stabilization, as normally would be required. Septage dewatering can be drastically improved by freezing. Since no chemicals are required, the cost is lower, but neither is stabilization achieved nor can this method be practiced on a year round basis, even in northern climates.

Costs

A summary of costs of various existing and proposed septage treatment systems has been compiled in Table 22. A brief description of each process is given along with design information, cost data, year applicable to the cost data, and system comments. The cost data is detailed into yearly capital and operation and maintenance costs on a 20 year amortization schedule, discounted at 7% per year.

TABLE 27 SUMMARY OF COSTS OF SEPTAGE TREATMENT SYSTEMS.

Process or System and Location	Design Flow m^3/day	Design Loading	Annual Costs/\$3.79 m^3			Cost Base	Reference
			Capital	O & M	Total		
1. Spray irrigation center pivot - sewage	1137	5 cm/week	0.19	0.18	0.37	1973	79
2. Spray irrigation center pivot - sewage	1137	10 cm/week	0.16	0.13	0.29	1973	79
3. Spray irrigation solid set - sewage	1137	5 cm/week	0.26	0.15	0.41	1973	79
4. Spray irrigation solid set - sewage	1137	10 cm/week	0.19	0.12	0.31	1973	79
5. Spray irrigation MSD Chicago - sludge	6.8 x 10^6 wet Kg	0.17 x 10^6 dry Kg/ha/yr			5.67	1973	80
6. Surface spreading EPA - sludge	1137	5 cm/week	0.20	0.19	0.39	1973	79
7. Surface spreading EPA - sewage	1137	10 cm/week	0.17	0.15	0.32	1973	79
8. Surface spreading EPA - sludge	23.9		1.05	3.57	4.62	1971	80
9. Surface spreading Xenia, OH - sludge	43.3		0.58	2.03	2.61	1972	80
10. Surface spreading U. S. Navy Boardman Bombing Range, OR - septage					8.00	1975	7
11. Land application nationwide sludge average			16.98	13.77	30.75	1976	81
12. Subsurface disposal Tomkins County, NY - septage	32		10.51	6.87	17.38	1976	21
13. Subsurface disposal Tomkins County, NY - septage	32		17.12	10.99	28.11	1976	21
14. Subsurface disposal Tomkins County, NY - septage	32		21.06	9.16	30.22	1976	21
15. Subsurface disposal - septage	19.6	30,000 PE	1.08	3.29	4.37	1972	1
16. Subsurface disposal - septage	190	1124 - 4495 m^3 ha/yr	2.50	3.13	5.63	1977	82
17. Subsurface disposal CO State University - septage	95	674 m^3/ha/yr	5.64	5.40	11.04	1977	83
18. Lagoon system Tomkins County, NY - septage	32		5.72	5.49	11.21	1976	21
19. Lagoon system Tomkins County, NY - septage	32		9.57	7.78	17.35	1976	21
20. Lagoon system Wayland, MA - septage	25	25 day retention 0.13 m^3/m^2/day on leaching beds	0.32	0.48	0.80	1969	71
21. Marsh/pond Upton, NY - septage and sewage	945	0.19 m^3/m^2/day total area	0.26	0.50	0.76	1977	77
22. Meadow/marsh/pond	945	0.38 m^3/m^2/day total area	0.31	0.75	1.06	1977	Author's Estimate
23. Landfill construction grants - sludge data			23.38	17.13	39.51	1976	81
24. Landfill EPA Sludge Manual		61 cm layers	3.97	19.86	23.83	1974	80
25. Landfill various NJ sites - septage		0.014 m^3/m^3 solid waste			25.0 - 70.0	1975	7
SEPARATE SEPTAGE TREATMENT FACILITIES							
26. Landfill Brunswick, ME - septage	up to 78 m^3/day			0.50		1973	84
27. Aerated lagoon Douglas County, OR - septage	5	1/2 - 2 yr detention in aerated lagoon	12.69	5.40	18.09	1972	85
28. Settling tanks/leaching beds Wayland, MA - septage	38	1.5 day settling tank; 0.09 m^3/m^2/day in leaching beds	0.69	1.61	2.30	1969	71

(continued)

TABLE 22. (continued)

Process or System and Location	Design Flow m^3/day	Design Loading	Annual Costs/\$3.79 m^3			Cost Base	Reference
			Capital	O & M	Total		
29. Settling tanks/leaching beds Sudbury, MA - septage	38	2 day settling tank 0.03 m^3/m^2/day in leaching beds	1.14			1969	50
30. Thickener vacuum filter Wayland, MA - septage	38	1.5 day retention in thickener; 6.8 m^3/m^2/day vacuum filter area	2.98	1.62	4.60	1969	71
31. Equalize clarify RBC Wayland, Sudbury, MA - septage	95	0.04 m^3/m^2 total disc area sand filters 59 m^3/m^2/day; infiltration 0. m^3/m^2/day	16.76	11.38	28.14	1975	51
32. Anaerobic digestion RBC Wayland, Sudbury, MA - septage	95	2 stage digest 1st - 7 days, 2nd - 14 days; 0.04 m^3/m^2 total disc area; sand filters 59 m^3/m^2/day; infiltration 0.2 m^3/m^2/day	21.49	14.71	36.20	1975	51
33. Thermophillic aerobic digester ME - septage	138	0.2 m^3/m^3 digester	1.02	14.60	15.62	1974	86
34. Composting Lebo process - septage	29	40,000 PE; 50 - 60% moisture in sawdust mixture	5.70	21.82	27.52	1975	87
35. Composting Lebo process - septage	95	50 - 60% moisture in sawdust mixture	1.43	6.03	7.45	1976	Western Minerals Letter
36. Compositng Lebo process Tacoma, WA - septage	57	0.02 sawdust per m^3 septage	1.29	5.76	7.05	1975	88
37. Composting Beltsville process Rehoboth, MA - septage	57	1.2 m^3 sawdust/m^3 septage, 3 - 6 months	6.04	33.16	39.20	1977	89
38. Composting Beltsville process Beltsville, MD - sludge	180				5.67	1975	47
39. Chemical oxidation Brunswick, ME - septage	10.4		46.20	3.55	49.75	1973	84
40. Chemical oxidation Ventura, CA - septage	264		7.05	9.24	16.29	1975	90
41. Chemical oxidation Wayland, Sudbury, MA - septage	95	2 day equalization; 2 Purifax units at 35 GPM each; sand filters 59 m^3/m^2/day; infiltration beds 0.2 m^3/m^2/day	21.49	14.71	36.20	1975	51
42. Chemical oxidation Babylon, NY - septage	2500		0.20	0.74	0.94	1965	91
43. Chemical oxidation Portland, OR - septage	76	2 Purifax units at 35 GPM each	2.59	16.19	18.78	1971	70
44. Chemical precipitation Oyster Bay, NY - septage	455	Sand recharge at 0.12 m^3/m^2/day; vacuum filter 48.9 m^3/m^2/day	0.60	6.25	6.85	1968 1974	49
45. Chemical precipitation Islip, NY - septage	910	Sand recharge at 0.12 m^3/m^2/day; vacuum filter 24.4 m^3/m^2/day	0.58	0.91	1.49	1968	49
46. Chemical stabilization Lebanon, OH - septage sand drying beds	19	28.4 m^3/m^2 septage in sand drying beds; pH to 11.5 - 12.0	13.69	19.04	32.73	1975	15

(continued)

TABLE 22. (continued)

Process or System and Location	Design Flow m^3/day	Design Loading	Annual Costs/$3.79 m^3			Cost Base	Reference
			Capital	O & M	Total		
SEPTAGE ADDITION TO SEWAGE TREATMENT PLANTS							
47. Pretreatment Westport, CT - septage	15		1.81			1964	59
48. Pretreatment Poughkeepsie, NY - septage	190		3.27			1976	21
49. Pretreatment Brunswick, ME - septage	4	0.05% flow	2.50	13.90	15.50	1972	11
50. Activated sludge Tomkins County, NY	32		10.49	19.23	29.72	1976	21
51. Activated sludge Tomkins County, NY - septage	32		27.47	8.24	35.71	1976	21
52. Activated sludge Poughkeepsie, NY - septage	190		7.25	3.95	11.20	1976	92
53. Activated sludge Tri Municipal Area (near Poughkeepsie, NY) - septage	231	0.44% flow	9.87	2.73	12.60	1976	92
54. Activated sludge Palo Alto, CA - septage	16.6	0.05% flow	4.48	4.76	9.24	1974	93
55. Activated sludge South Bend, IN	1.9	0.002% flow			30.00	1976	7
56. Activated sludge Cleveland, OH	114	0.04% flow			5.32	1976	7
57. Aerobic digestion Fort Collins, CO - sludge	227	25 day SRT 0.43 Kg vs/m^3/day	1.92	2.08	4.00	1977	83
58. Aerobic digestion Bend, OR - septage and vault toilet wastes	20.5	15 day SRT 0.32 Kg vs/m^3/day	7.78	6.37	14.15	1973	68
59. Anaerobic digester Tallahassee, FL - septage	13.5	82 day SRT 0.16 Kg vs/m^3/day			1.97	1976	7
60. Anaerobic digester Japan - night soil	30	30 day SRT	0.71	0.40	1.11	1962	94
61. Anaerobic digester Japan - night soil	30	15 day SRT	0.97	0.57	1.54	1962	94
62. Anaerobic digester Wayland, MA - septage	25	25 day SRT vac filter 4.42 m^3/m^2/day	5.76	1.62	7.38	1969	71
63. Anaerobic digester Wayland, MA - septage	25	25 day SRT leaching beds 0.13 m^3/m^2/day	3.77	1.61	5.38	1969	71
64. Wet air oxidation Poughkeepsie, NY - septage	190		6.75	3.38	10.13	1976	92
65. Wet air oxidation Ventura, CA - septage	246		4.58	5.03	9.61	1971	95

A survey of 42 sewage treatment facilities was performed in this study (Figure 39). All processes reported were included, including liquid stream treatment, aerobic digestion, and anaerobic digestion. Survey results showed that only about half charged for septage disposal based on treatment costs. (78) Some charge prohibitive rates to avoid septage, while others place a minimal charge on septage to ensure against illegal dumping at an unauthorized site. For those plants surveyed, the average charge surveyed for septage was \$15.18 per 3.8 m^3 (1,000 gal). However, an additional 20 to 30 plants contacted either placed no charge on septage disposal or levied only a yearly fee, most often in the range of \$50.00 \$300.00 per truck.

Many variables affect treatment costs, including local funding requirements; eligibility for state or federal funds; necessity for industrial cost recovery formats; local taxes assessed in lieu of, or to offset, treatment plant expenses; level of design; climate; present loading vs design plant capacity; and cost of land. With this in mind, the broad range of charges for treatment plant septage disposal is easily understood.

A summary of alternatives investigated is shown in Table 23, with a representative range of costs for treating septage in various alternatives shown in Figure 39. This matrix arranges the alternatives by ordering the systems by cost effectiveness. If a septage treatment system is desired in a particular location, physical and environmental impacts would be evaluated for compatability with the surroundings. If valid objections in these areas do not arise, then this system should be chosen as the most cost-effective solution for the problem. If the solution does not meet local requirements, investigate the following system as the next most cost-effective answer. The procedure is continued until a system meeting all stipulated requirements is met.

Although research is required to answer various treatability, design, and operation questions, sufficient detailed information has been presented or referenced to assess the alternatives listed.

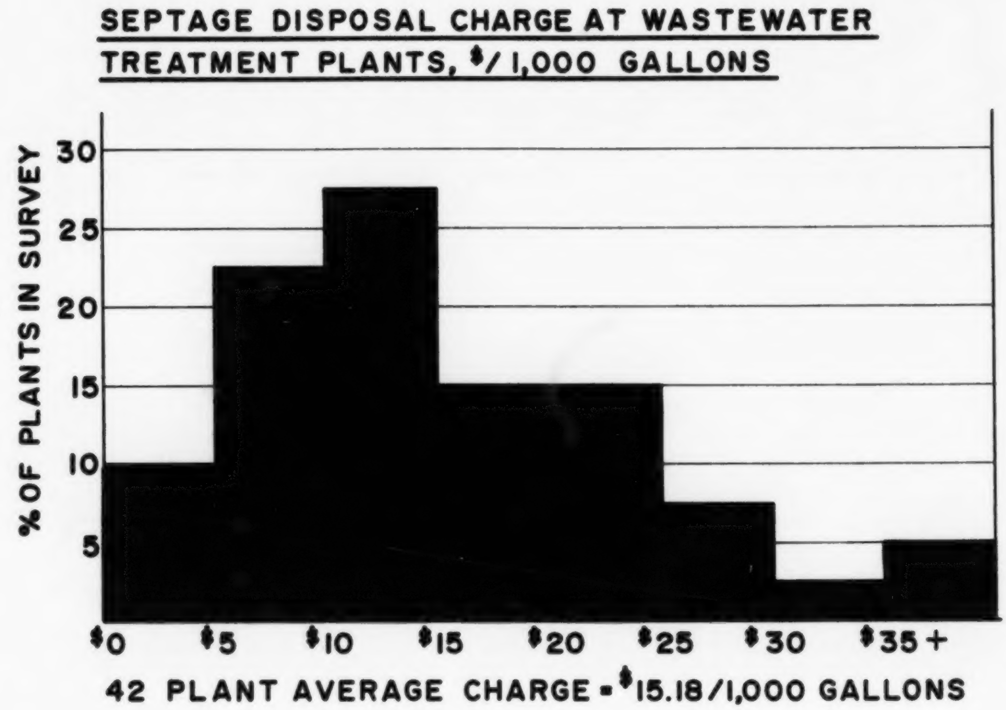


Figure 39. Summary of a survey of septage disposal charges at 42 United States sewage treatment plants. (78)

TABLE 23. RANKING OF VARIOUS ALTERNATIVE SEPTAGE TREATMENT PROCESSES*

Method Number	Conditioning Method	Disposal Category Treatment	Effluent Treatment	Solids
1	Marsh/Pond - Meadow Marsh Pond	Land	N/A	N/A
2	Surface Spreading Application	Land	N/A	N/A
3	Sanitary Landfill	Land	N/A	N/A
4	Lagoon Systems	Land	N/A	N/A
5	Subsurface Injection	Land	N/A	N/A
6	Anaerobic Lagoons	Separate	Infiltration Beds	Dry out
7	Aerobic Lagoons	Separate	Infiltration Beds	Dry out
8	Aerobic Digestion	Separate	Infiltration Beds	Vacuum Filter
9	Anaerobic Digestion	Separate	Infiltration Beds	Vacuum Filter
10	Anaerobic - Aerobic Digestion	Separate	Infiltration Beds	Vacuum Filter
11	Anaerobic Digestion	STP	Biological Treatment	Dewatering
12	Aerobic Digestion	STP	Biological Treatment	Dewatering
13	Composting	Separate	N/A	Sell as a conditioner
14	Activated Sludge	STP	Biological Treatment	STP Solids Stream
15	Trickling Filter	STP	Same Biological Treatment	STP Solids Stream
16	Chemical Coagulation	Separate	Infiltration Beds	Vacuum Filter
17	Lime Stabilization	Separate	Infiltration or Biological Treatment	Sand drying beds
18	Physical - Chemical Oxidation	Separate	Transport STP Biological Treatment	Lagoon or Sand Drying Beds

*Assigned rank determined on cost basis only.

(continued)

TABLE 23. (continued)

Treatment Method	Sensitivity of Process to						Cost to Treat per 3.8 m^3 (1,000 gal)			Estimated Use (%)	
	Odors	Vectors	Groundwater	Foaming	Climate	Precipitation	O & M	Capital	Total	Present	Future
1	L	M	M	M	M	M	L	L	L	0	1
2	H	H	H	L	H	H	L	L	L	40	20
3	H	H	H	L	M	H	L	L	M	5	1
4	H	M	H	L	M	H	L	L	M	20	20
5	L	L	M	L	H	H	L	M	M	0	5
6	H	M	H	L	M	M	L	M	M	2	4
7	M	M	H	H	M	M	M	M	M	2	4
8	M	M	H	H	L	L	M	M	M	0	2
9	M	M	H	L	L	L	M	M	M	0	2
10	M	M	H	H	L	L	M	M	M	0	2
11	M	L	L	L	L	L	M	M	M	3	7
12	L	L	L	H	M	M	M	M	M	2	8
13	M	M	L	L	L	L	M	M	H	1	3
14	L	L	L	H	L	L	M	M	H	19	10
15	H	M	L	M	L	L	M	H	H	1	0
16	L	M	H	L	L	L	H	M	H	2	4
17	L	M	M	L	L	L	H	M	H	0	3
18	L	L	L	L	L	L	H	M	H	3	4

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